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ABSTRACT

As a part of the REACH (Refrigeration, Electro-Mechanical, Air-Conditioning, Heating) electromechanical cluster, this postsecondary student manual contains individualized instructional units in the area of electricity. The instructional units focus on electricity fundamentals, electric motors, electrical components, and controls and installation. Each unit follows a typical format that includes a unit sheet, information sheets, assignment sheets, and job sheets. The unit sheet is designed to guide the learner through each task and is comprised of two main sections. The first lists all information needed to identify the task and the sequence in which activities are performed. The second section identifies each activity. (Related teacher's guides are available as CE 026 352, CE 026 354-355.) (LRA)

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REACH

ELECTRICITY UNITS
POST-SECONDARY

DEVELOPED UNDER CONTRACTUAL AGREEMENT

WITH

DIVISION OF PROGRAM DEVELOPMENT
OFFICE OF VOCATIONAL EDUCATION
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ATLANTA, GEORGIA 30334
CHARLES McDANIEL, STATE SUPERINTENDENT OF SCHOOLS

BY

VOCATIONAL EDUCATION TEACHERS

AND

THE UNIVERSITY OF GEORGIA STAFF

UNDER THE DIRECTION

OF

DR. PAUL SCOTT

VOCATIONAL EDUCATION MATERIALS CENTER
DIVISION OF VOCATIONAL EDUCATION
COLLEGE OF EDUCATION
UNIVERSITY OF GEORGIA
ATHENS, GEORGIA 30602

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JUNE, 1980

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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MAJOR BLOCK Electricity **NAME** _____

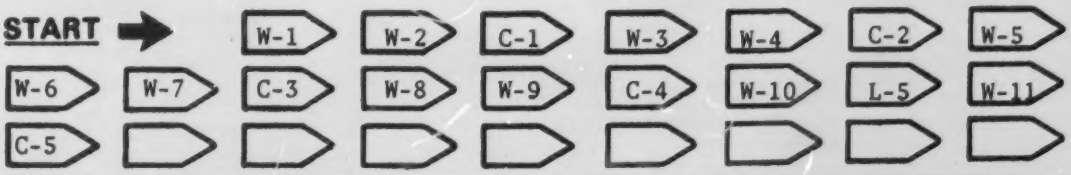
TASK Fundamentals

UNIT Basic Electrical Theory **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-01

OBJECTIVE(S)

Demonstrate an understanding of basic electrical theory.



WRITTEN ASSIGNMENTS

W-1 Information Sheet EL-01a
W-2 Assignment Sheet EL-01a
W-3 Text Assignment EL-01a
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Electrical Safety

Safety is of prime importance when people are involved in activities that require close working conditions with electricity. Each year, many accidents involving electricity occur both in the home and in industry. The major cause of electrical accidents in the home is improper wiring or faulty wires. The major cause of electrical injury or death in the heating, cooling, and refrigeration industry is carelessness. It is imperative that people who enter the industry have a knowledge of the damage and harm which can be caused by an electrical shock to the human body.

The effect of the flow of electrons through the human body ranges from a tingle produced by static electricity to a powerful electrical shock from lightening or high voltage. There are many unstable factors in the human body. There is not specific strength of an electrical shock which causes a tingle, unpleasant sensation, serious injury, or death. If a person is properly grounded it only takes a small electrical potential to cause serious injury or death. Electrical shock may cause severe burns, unconsciousness or other serious problems, but death by an electrical shock usually results from breaking the rhythm of the heart.

Almost all electrical accidents can be prevented by respecting electricity and concentrating intensely on the task at hand. Any person working on a piece of electrical equipment which maintains some type of electrical power supply, should always be cautious as to the position of hands or tools. Keep them away from bare wires or connections. Service personnel should always make sure that power has been disconnected before doing any major servicing. At times it will be necessary to troubleshoot equipment with the power supply "ON". The person doing such work should always be extremely cautious.

Occasionally service personnel will be required to troubleshoot electrical appliances or equipment that when touched will give an electrical shock. When this occurs you should approach the problem carefully because the wrong move can cause severe injury. Before checking equipment out in this situation make sure the power is "OFF" for the initial inspection. It may be necessary to restore power if the first inspection shows no faulty wiring. Faulty grounding occasionally causes this problem.

The service technician should be aware that a person receiving a severe electrical shock may still be in contact with the electrical source. Before air is given to an electrical shock victim make sure that no contact is being made with the appliance. If contact is being made the rescuer should disconnect power if possible. If this is impossible, get a long, dry wooden stick to move the victim or use heavy rubber gloves. When the victim is removed, the necessary first aid should be applied and help sent for. If the person is unconscious then CPR should be given in an attempt to save the victim's life.

In summary, any person working with electricity should always respect it. Caution should be used whenever it is necessary to work on equipment which is still connected to power. Many accidents are indirectly caused by electricity. Workers sometimes hurt themselves while attempting to get away from an electrical shock or sparks caused by an electrical short. The best remedy for an electrical shock is to avoid receiving it.

Answer the following questions:

1. How many volts are required to cause serious injury?

2. What is the major cause of electrical accidents in the home and industry?

3. What effect does an electrical shock have on the heart?

4. What precaution should be taken when attempting to give someone first aid after a severe electrical shock?

5. Name five precautions that should be used where working with electrical equipment.

Answer the following questions:

1. What is matter?

2. What is an element?

3. Briefly explain the parts and the composition of an atom.

4. What atoms does one molecule of F-22 contain?

5. State the law of electric charges.

Answer the following questions:

1. Name three common methods of creating a flow of electrons (electricity) and explain each.

2. How does a generator produce a flow of electrons?

3. Define a conductor.

4. What is an insulator and give at least three examples?

5. What is the physical difference between a conductor and an insulator?

Answer the following questions:

1. What is an electrical circuit?

2. Describe electrical pressure and list the terms used to describe it.

3. What is a volt, ohm, and ampere?

4. Using a water system as a reference, explain the relationship of volts to water pressure, amperes to quantity of water, and resistance to the pressure drop.

5. What is the result if the following conditions change in a water system?

   a. larger pressure drop in lines

   b. less pressure being applied to system

   c. quantity of water is increased

6. What is the result if the following conditions change in an electrical system?

   a. increase in resistance

   b. drop in voltage

   c. increase in amperes

7. What term is used to measure?

   a. EMF

   b. current

   c. resistance

Answer the following questions:

1. What part does the make up of atoms and molecules play in electricity?

2. Give three examples of how the flow of electrons can be accomplished in an electrical circuit.

3. What is the difference between a storage battery and a dry cell battery?

4. Define the following terms:

   a. volts

   b. amperes

   c. ohms

   d. milli-

   e. kilo-

   f. conductor

   g. insulator

   h. electrons

MAJOR BLOCK Electricity **NAME** _____

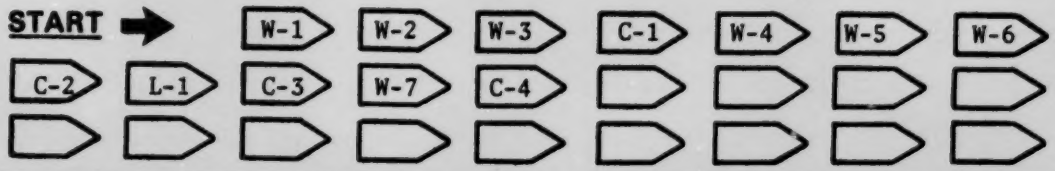
TASK Fundamentals

UNIT Computing Ohm's Law & Power Formulas **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-02

OBJECTIVE(S)

You will be able to answer correctly 9 out of 12 questions and problems on Ohm's Law and Power calculations on a written test.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-02a
W-2 Information Sheet EL-02a
W-3 Assignment Sheet EL-02a
W-4 Text Assignment EL-02b
W-5 Information Sheet EL-02b
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W-7 Assignment Sheet EL-02c

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

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L-2 _____
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Ohm's law is the relationship between the voltage, current and resistance in an electrical circuit. Stated in simple terms, according to Ohm's law, one volt applied across a resistance of one ohm will produce a current of 1 amp. Ohm's law would be stated as:

A. Current = $\frac{\text{Voltage}}{\text{Resistance}}$

B. Amperes = $\frac{\text{Volts}}{\text{Ohms}}$

C. (1) $I = \frac{E}{R}$

(2) $E = IR$

(3) $R = \frac{E}{I}$

I = Amperage - Current

E = Volts - Voltage

R = Ohms - Resistance

Rules that should be remembered when using Ohm's law or other electrical formulas are:

1. All formulas are based on fundamental units, unless it is specified as being special. Ohm's law is based on the volt, amp, and ohm. If any other units are used they must be converted to the standard units.

2. All values used in Ohm's law must pertain to the same part of the circuit.

I. Work the following problems:

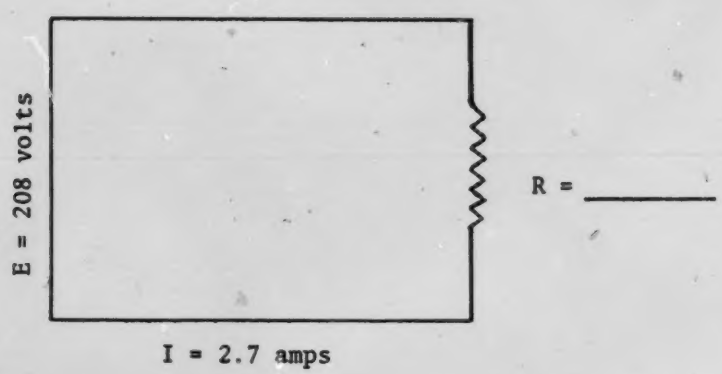
1. An electric heater is hooked up to 115 volts and uses 6 amperes. What is the resistance of the heater?

2. An electric heater with a resistance of 8 ohms is hooked up separately on 120, 208, and 230 volts. What would be the current used by the heater when using each voltage?

3. A 12 ohm resistor is placed in a circuit; the circuit used 28 amps. What is the voltage available to the resistor?

4. The resistance of a 65 watt and 25 watt 120 volt bulb are 194 ohms and 570 ohms respectively. What is the amp draw of a 75 watt bulb and a 25 watt bulb?

5. Calculate the resistance of the crankcase heater in the diagram shown below.



6. What would the amperage be of an electric heater if the resistance was 12 ohms and installed on 250 volts?

Power Formula

Formulas used for power calculations will be stated as:

A. Power = Current x Voltage

B. Watts = Amperes x Volts

C. (1) $P = IE$

(2) $E = \frac{P}{I}$

(3) $I = \frac{P}{E}$

(4) $E = \frac{P}{I}$

(5) $P = I^2R$

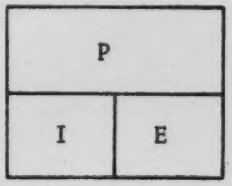
(6) $P = \frac{E^2}{R}$

P = Watts - Power

I = Amperes - Current

R = Ohms - Resistance

E = Voltage



Helpful conversion factors are:

1 Hp = 746 watts

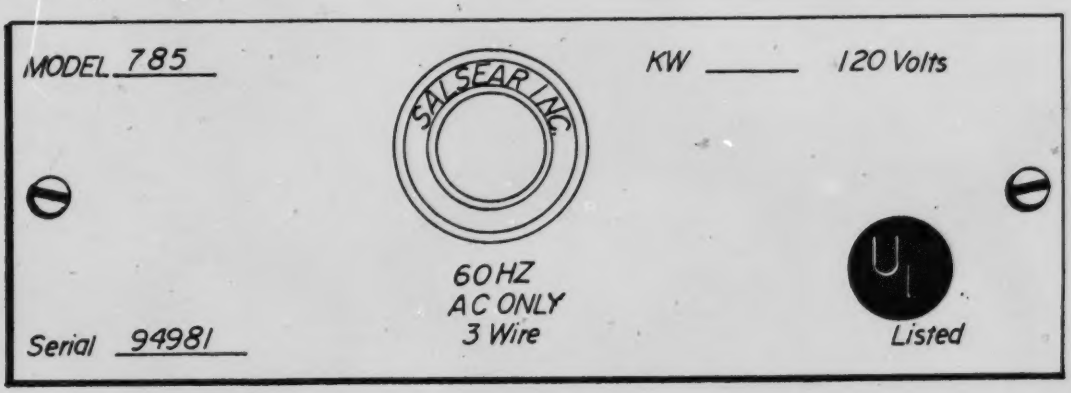
1 KW = 1.34 horsepower

1 watt = 3.41 Btu/hr.

1 kilowatt = 3.410 Btu/hr.

Use the Power formulas to compute the following problems:

1. What is the wattage of an electric heater with a current draw of 20 amps connect to 240 volts?
2. What is the wattage of an electric iron with a resistance of 8 ohms and a current draw of 12 amperes?
3. What is the power consumed by an electric heater with a current of 26 amps on 460 volts in kilowatts?
4. What is the current draw of an electric heater rated at 6000 watts on 230 volts?
5. What is the Btu/hr. output of a 15 kilowatt heater?
6. Determine the current draw from the following data plate:



Locate the data plate on three pieces of equipment or tools in the lab and determine the following electrical characteristics. Some information will be listed on the data plate. Use Ohm's Law and the Power Formula to determine the additional information.

Item #1

Type and Manufacturer_____ Serial Number_____

A. Voltage_____

B. Amperage_____

C. Resistance_____

D. Wattage_____

Item #2

Type and Manufacturer_____ Serial Number_____

A. Voltage_____

B. Amperage_____

C. Resistance_____

D. Wattage_____

Item #3

Type and Manufacturer_____ Serial Number_____

A. Voltage_____

B. Amperage_____

C. Resistance_____

D. Wattage_____

A. Answer the following TRUE/FALSE question. If the statement is false rewrite, correcting it.

1. Ohm's law is valid on all types of AC & DC circuits.

2. Ten thousand watts equals one kilowatt.

3. For a given material, resistance increases as the diameter of the conductor decreases.

4. A 10 watt heater would produce 3,140 Btu/hr.

5. If the resistance of an electrical circuit is increased; while the voltage remains the same, the amperage of the circuit will decrease.

6. If the current of an electrical circuit is increased; while the voltage remains the same, the resistance of the circuit will increase.

7. The voltage drop of an electrical circuit should be kept under 2%.

8. Ohm's law is the relationship among the current, electromotive force, and power of an electrical circuit.

B. Work the following problems:

1. What would be the current draw of a heater rated at 12,000 watts on 230 volts?

2. What should the resistance of a crankcase heater on 230 volts drawing 1.5 amps?

3. What voltage is being supplied to a circuit that has a resistance of 12 ohms and current draw of 25 amps?

4. If an electric heater is rated at 25 KW on 230 volts, what would its current draw be?

MAJOR BLOCK Electricity **NAME** _____

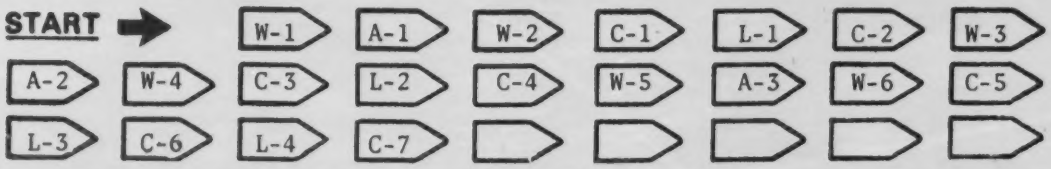
TASK Fundamentals

UNIT Using Electric Meters **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-03

OBJECTIVE(S)

Read the voltage, amperage, and ohms of 20 different points in the shop.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-03a
W-2	Assignment Sheet EL-03a
W-3	Text Assignment EL-03a
W-4	Assignment Sheet EL-03b
W-5	Text Assignment EL-03c
W-6	Assignment Sheet EL-03c
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-03a
A-2	Slide Set EL-03b
A-3	Slide Set EL-03c
A-4	
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A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-03a
L-2	Job Sheet EL-03b
L-3	Job Sheet EL-03c
L-4	Job Sheet EL-03d
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L-7	
L-8	
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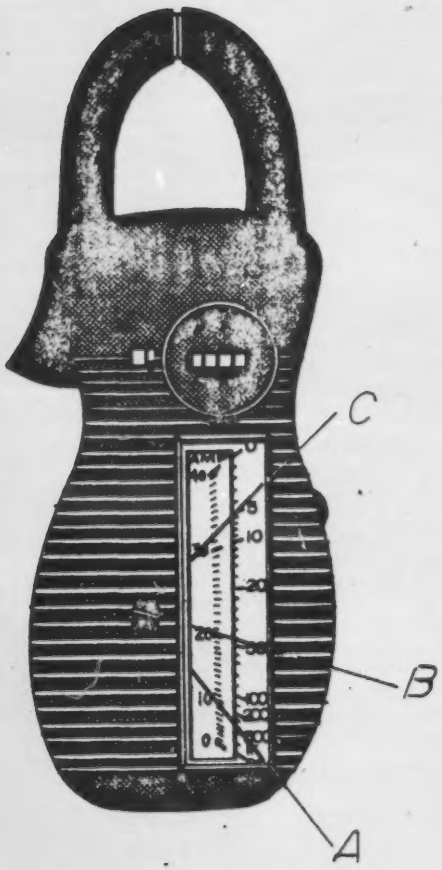
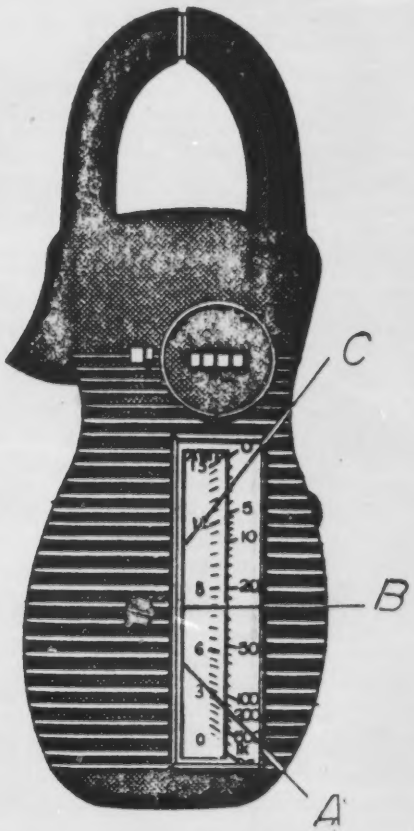
CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	Instructor Check
C-7	Instructor Check
C-8	
C-9	

I. Read the following clamp on ammeter scales. (If a stationary meter face is shown note the selector switch setting). The interpretation of the sclae on an ammeter is very similar to that of a refrigeration guage if the needle falls between two readings.





Readings A_____

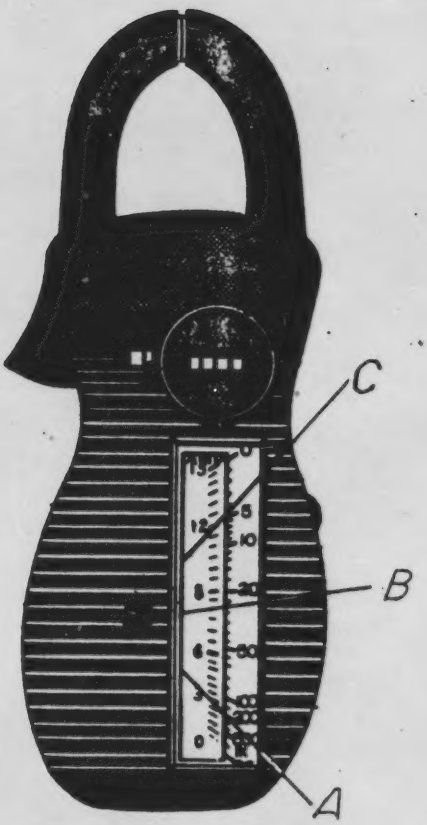
B_____

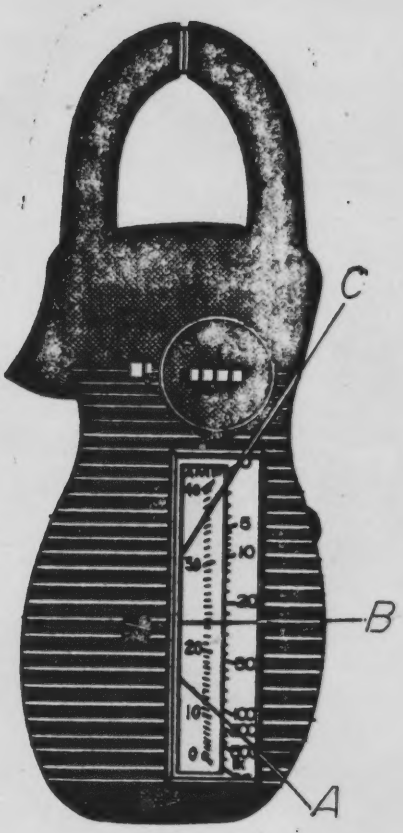
C_____

Readings A_____

B_____

C_____





Readings A_____

B_____

C_____

Readings A_____

B_____

C_____

A. The instructor should observe as the student sets the meter and reads the current of the following loads:

1. 100 watt light bulb _____ Amps
2. electric heater (cone) _____ Amps
3. compressor _____ Amps
4. compressor _____ Amps
5. fan motor _____ Amps

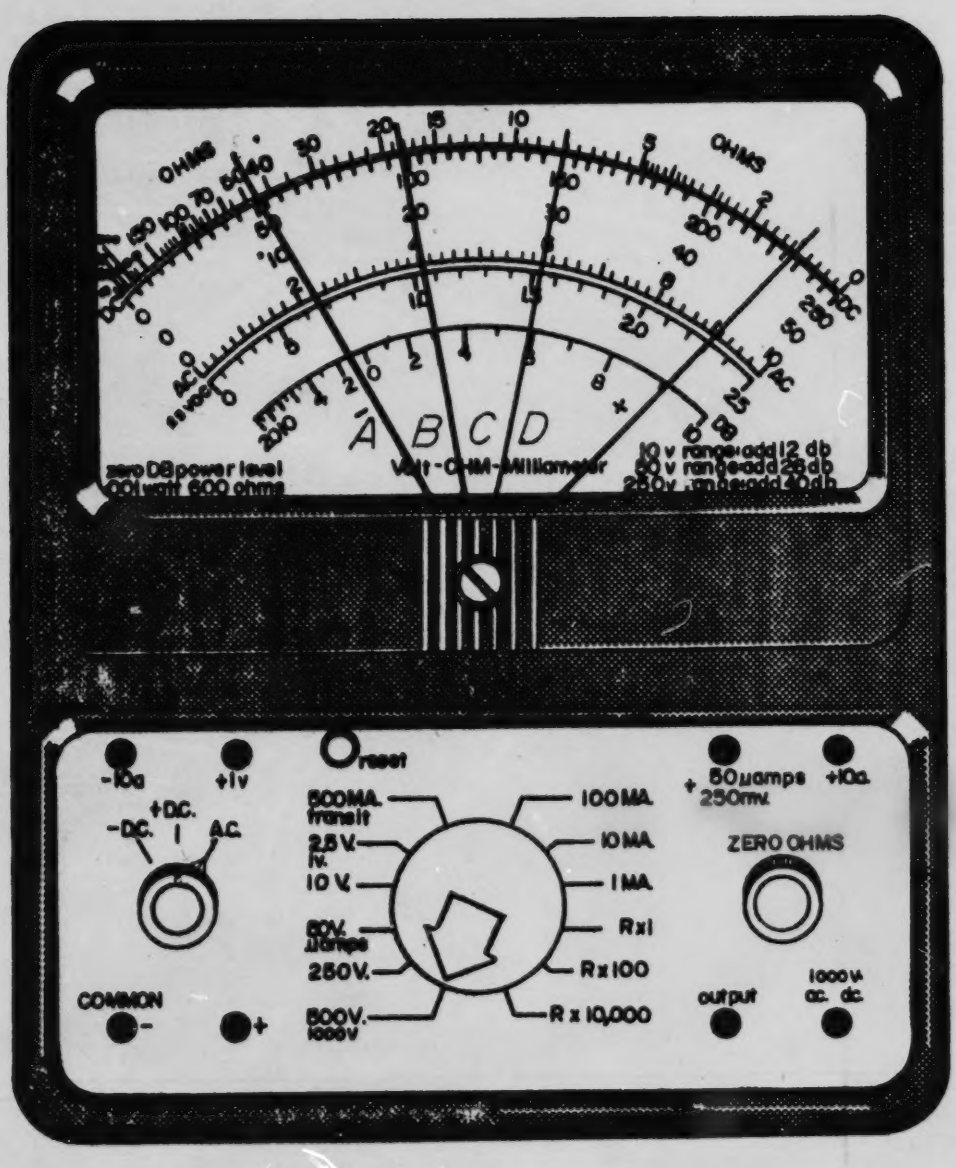
B. Read the current of the 10 loads below. (unassisted)

1. compressor residential A/C _____ Amps
2. condenser fan motor _____ Amps
3. electric resistance heater of heat pump _____ Amps
6. an electrical panel _____ Amps
7. indoor for motor of pkg. unit _____ Amps
8. compressor of refrigerator _____ Amps
9. cooling tower pump _____ Amps
10. vacuum pump motor _____ Amps

1. Read the following VOM scales. Pay attention to the selector switch setting.

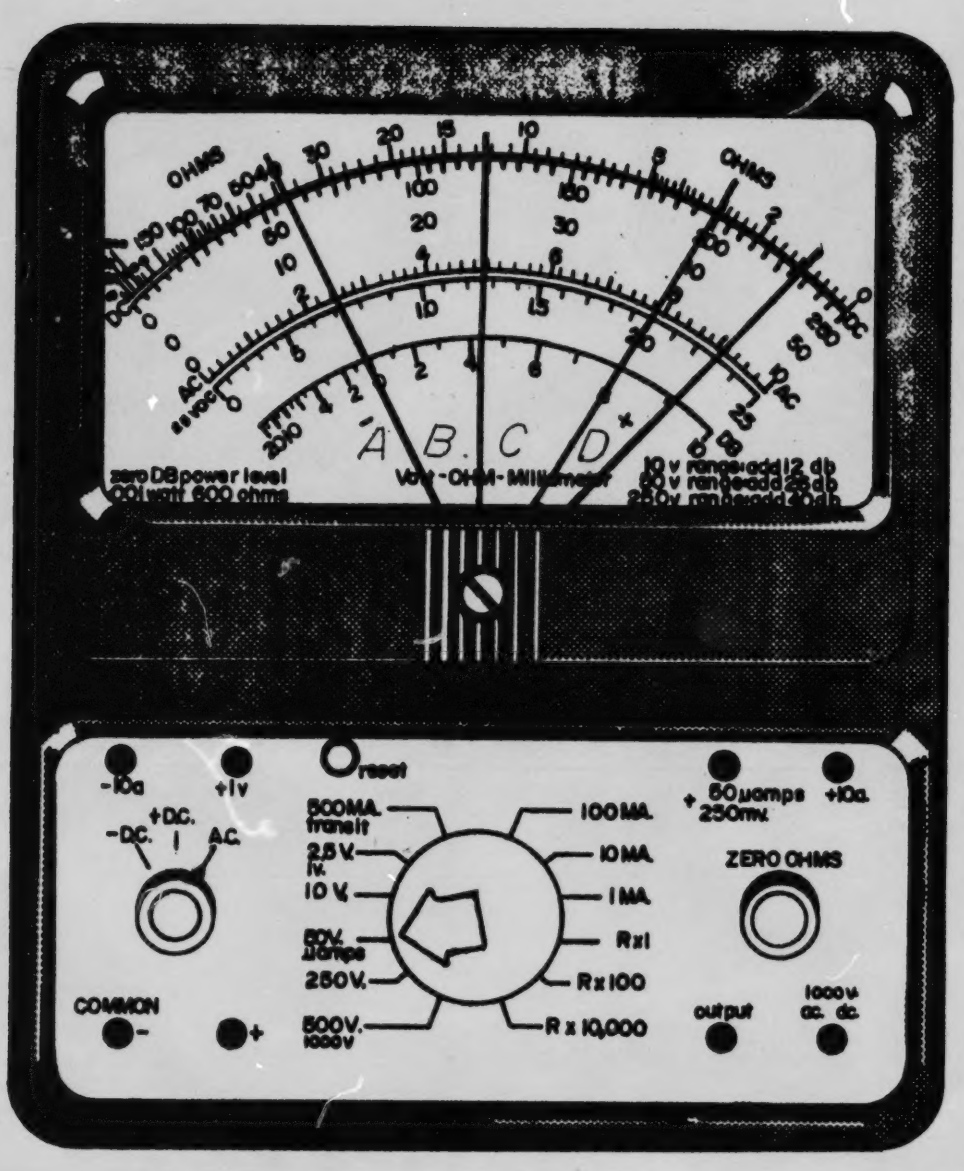
Readings A_____ C_____

B_____ D_____



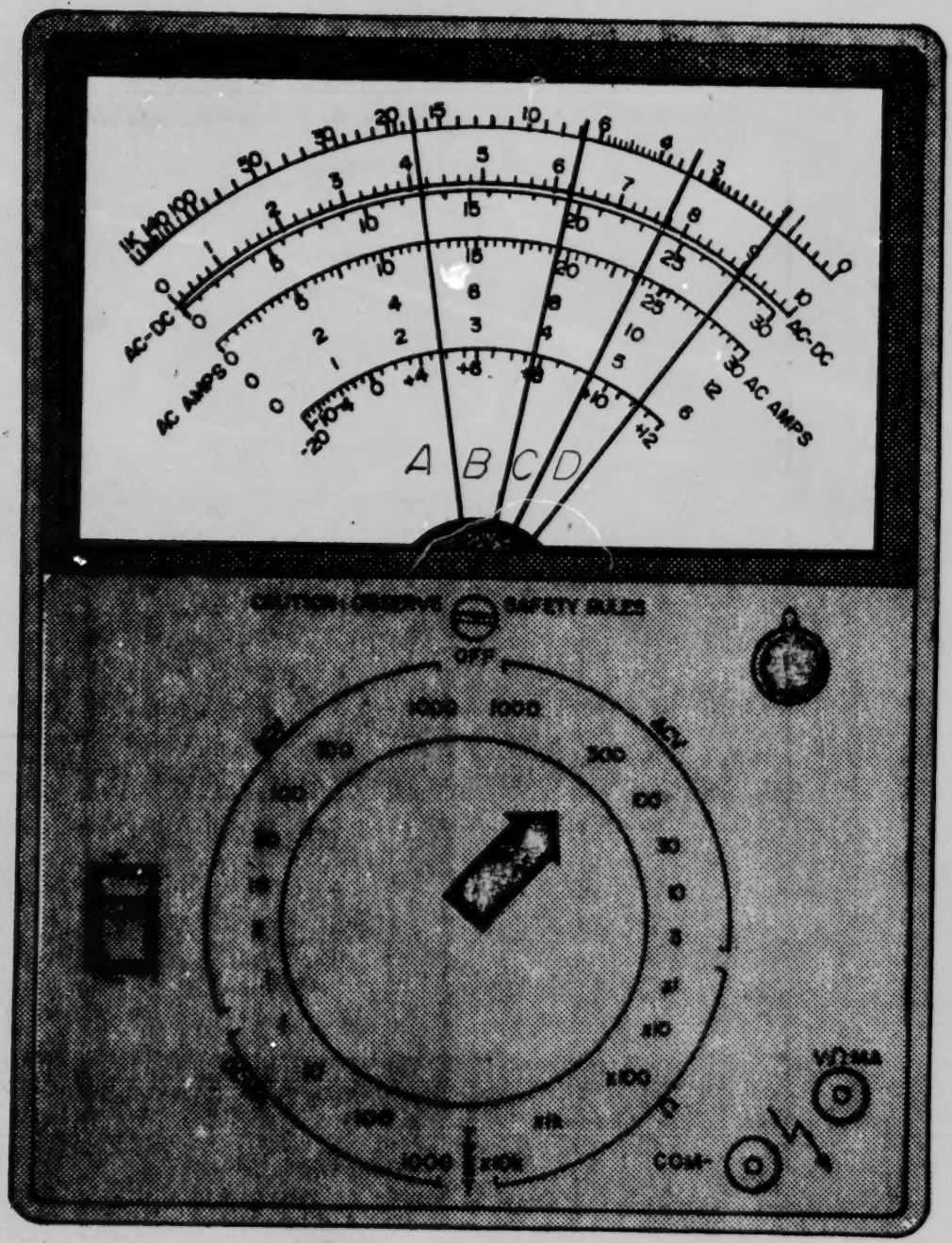
Readings A_____ C_____

B_____ D_____



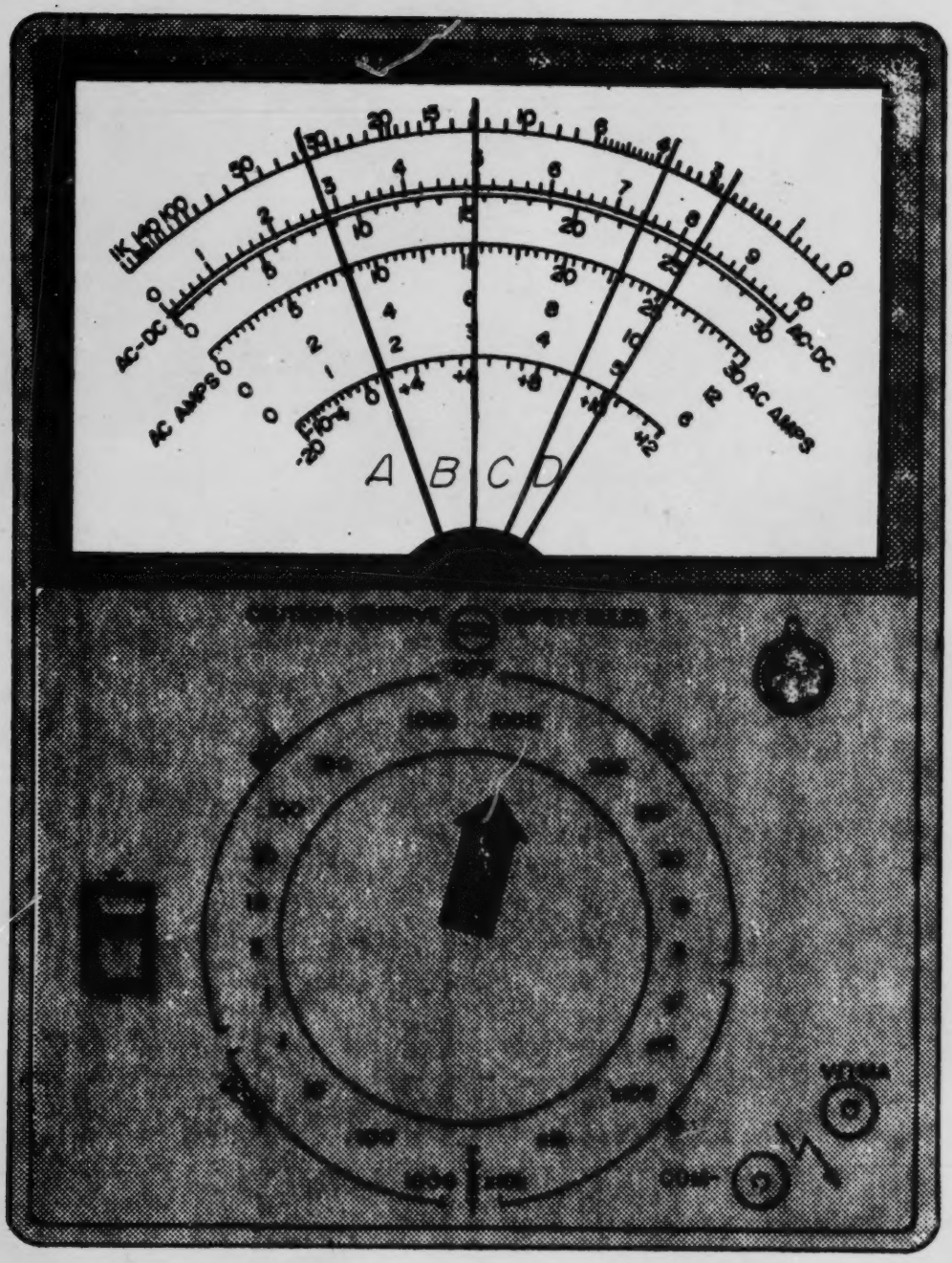
Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____

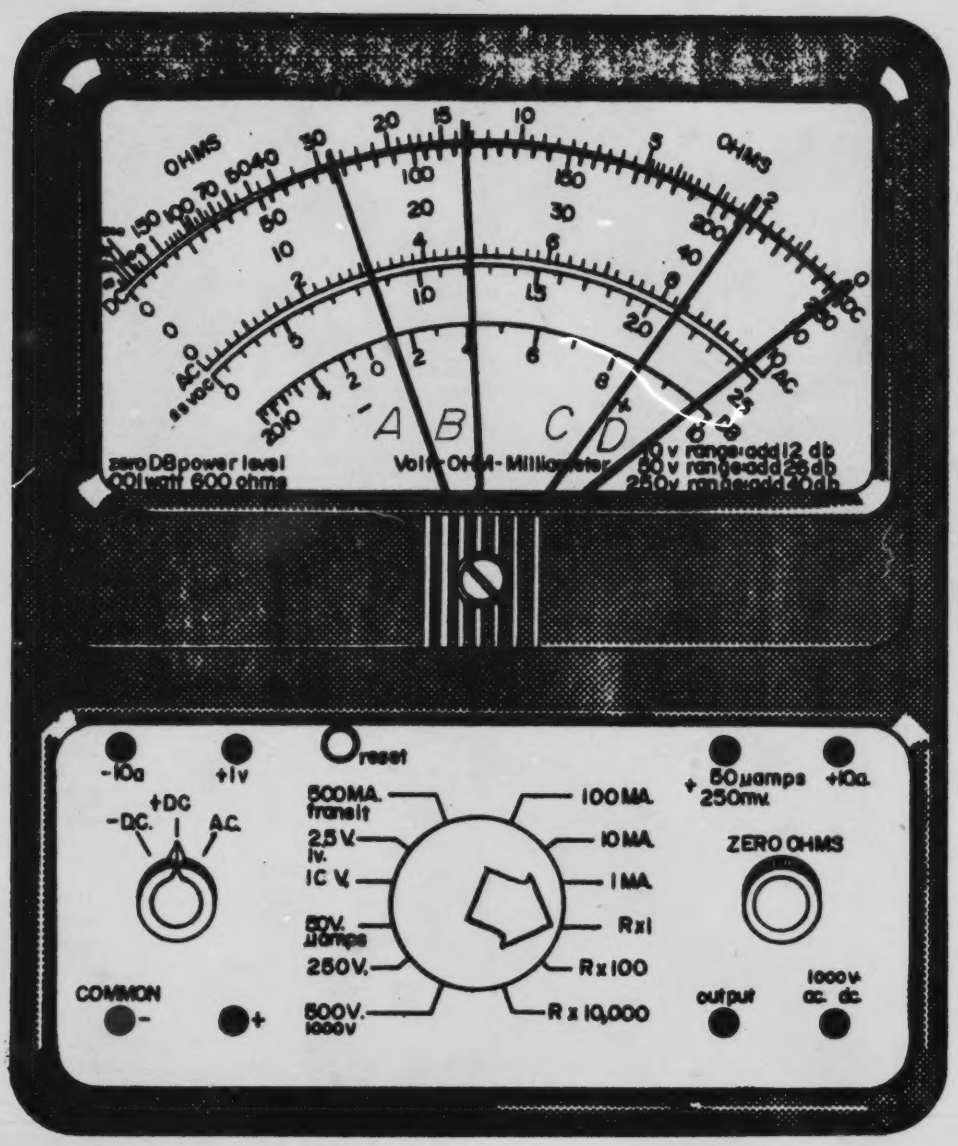
A. The instructor should observe as the student sets the meter and reads the voltage on the following pieces of equipment.

1. A/C unit _____ volts
2. Refrigerator _____ volts
3. Elec. Panel _____ volts
4. Transformer (high voltage) _____ volts
5. Transformer (low voltage) _____ volts

B. Read the voltage of the 10 pieces of equipment below. (unassisted)

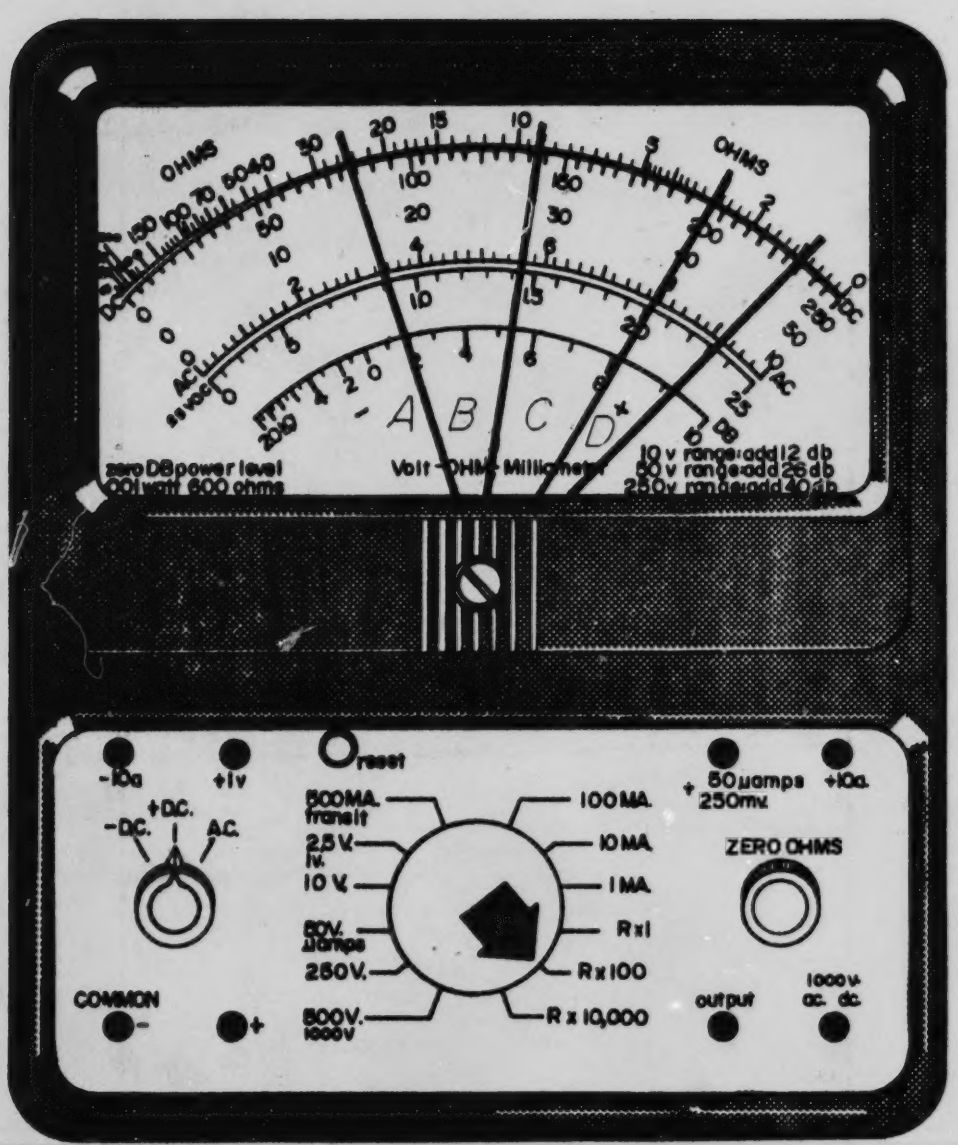
1. A/C unit _____ volts
2. A/C unit _____ volts
3. Refrigerator _____ volts
4. Elec. Panel (high voltage) _____ volts
5. Elec. Panel _____ volts
6. Transformer (high voltage) _____ volts
7. Motor _____ volts
8. Relay coil _____ volts
9. Transformer _____ volts
10. Motor _____ volts

1. Read and record the dials on the following meter (note selector switch setting).



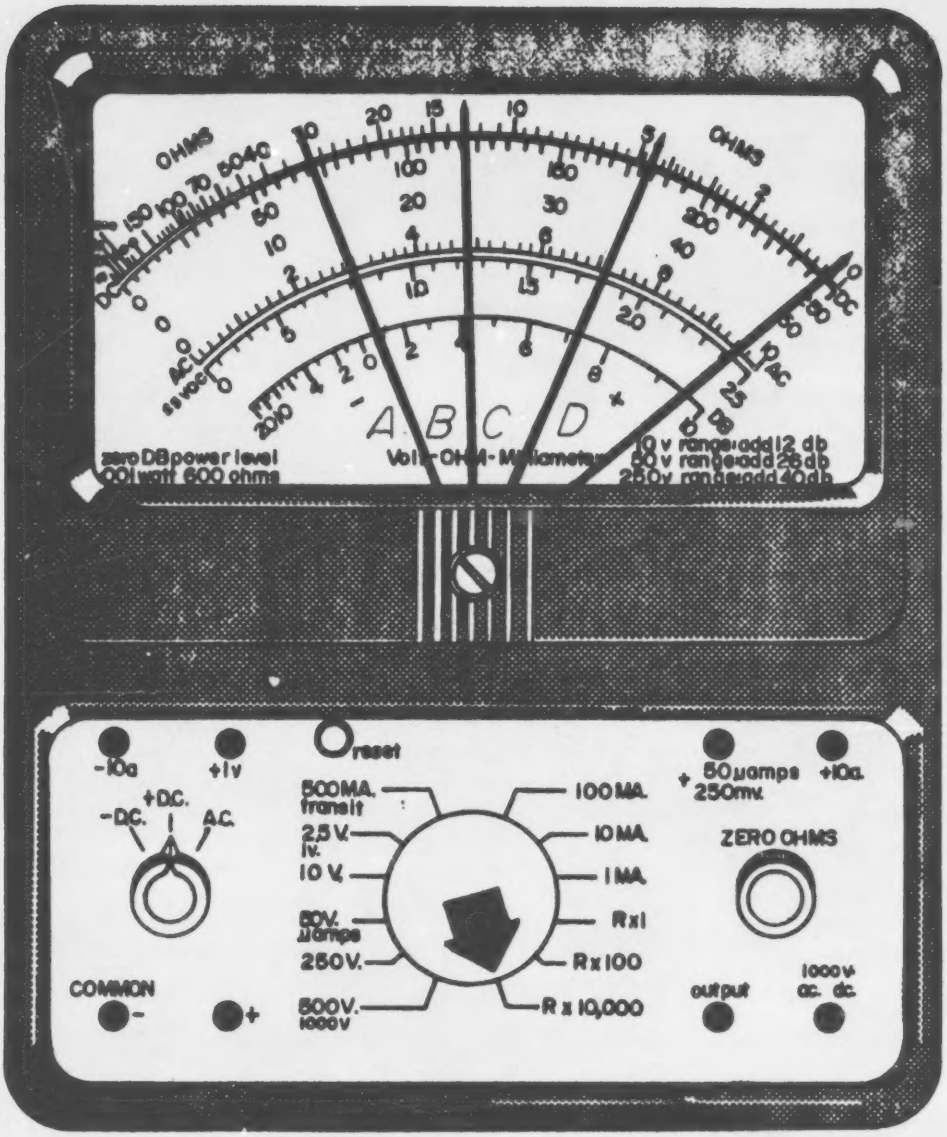
Readings A_____ C_____

B_____ D_____



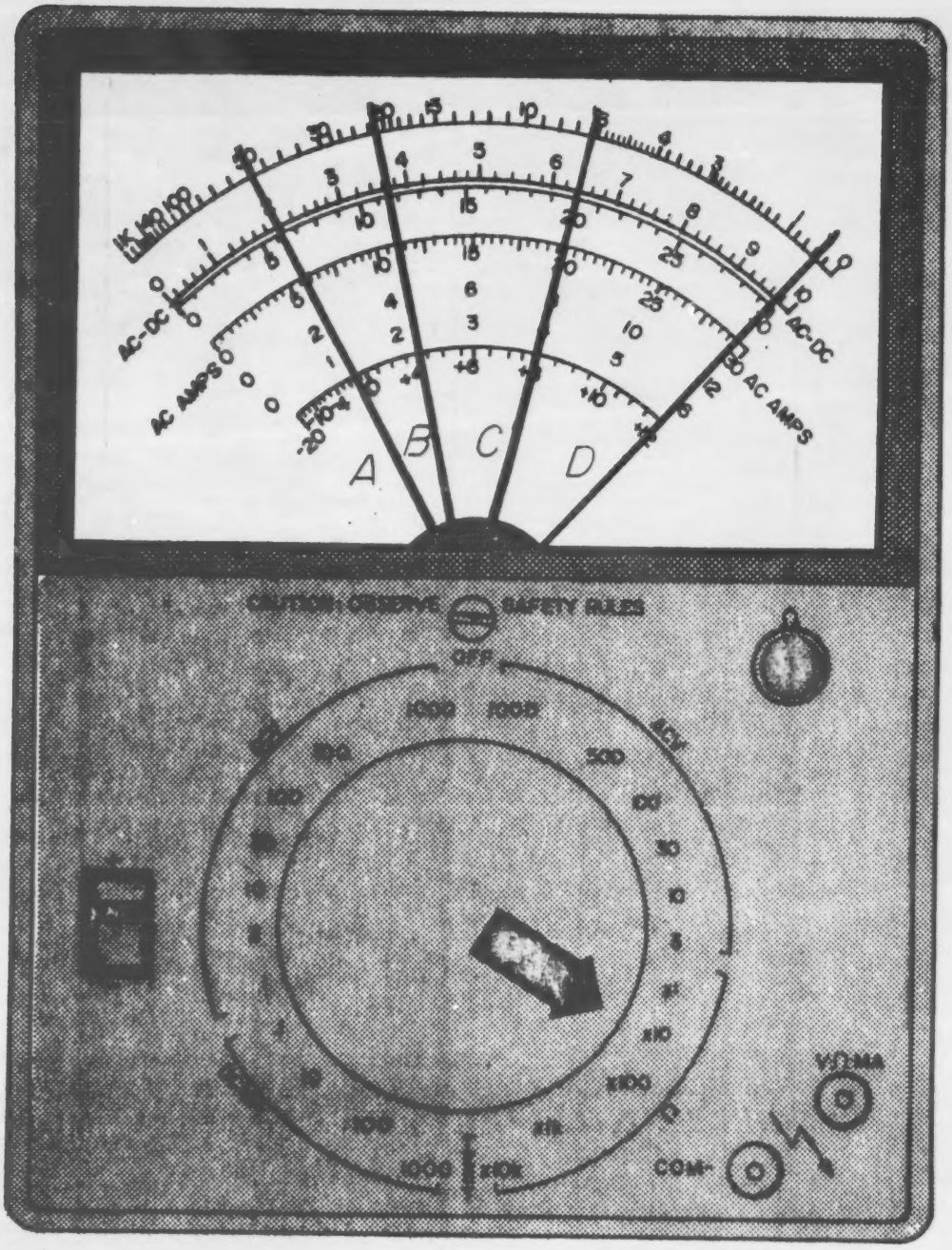
Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____

The instructor should observe as the student sets the meter and reads the resistance of the following components.

1. Fuse _____ Ω
2. Relay coil _____ Ω
3. Contactor coil _____ Ω
4. Resistor _____ Ω
5. Motor _____ Ω

Read the resistance of the 10 components below. (unassisted)

1. Fuse _____ Ω
2. Heater _____ Ω
3. Resistor _____ Ω
4. Relay coil _____ Ω
5. Motor _____ Ω
6. Compressor motor _____ Ω
7. Contactor coil _____ Ω
8. Thermostat contacts _____ Ω
9. Transformer _____ Ω
10. Transformer _____ Ω

A. Use the VOM, read the voltage, amperage and/or resistance of the following points or components in the shop.

1.	Elec panel	_____ A	_____ V	
2.	Fan motor	_____ A	_____ V	_____ Ω
3.	Compressor (3T)	_____ A	_____ V	_____ Ω
4.	Contactor coil	_____ A	_____ V	_____ Ω
5.	Resistor			_____ Ω
6.	24 volt transformer		_____ V	_____ Ω
7.	Compressor (ref.)	_____ A	_____ V	_____ Ω
8.	Condenser F. motor	_____ A	_____ V	_____ Ω

MAJOR BLOCK Electricity **NAME** _____

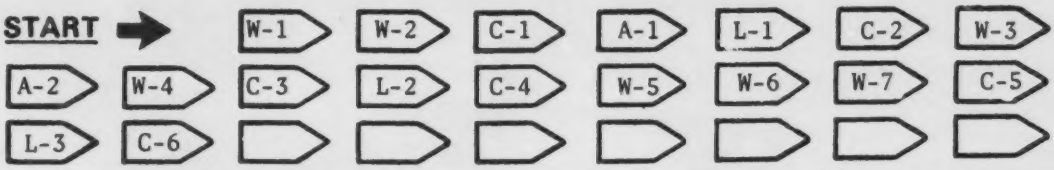
TASK Fundamentals _____

UNIT Demonstrate a Knowledge of Series and Parallel Circuits **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-04

OBJECTIVE(S)

Demonstrate a knowledge of and identify series, parallel and series/parallel circuits.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-04a
W-2	Assignment Sheet EL-04a
W-3	Text Assignment EL-04b
W-4	Assignment Sheet EL-04b
W-5	Text Assignment EL-04c
W-6	Information Sheet EL-04a
W-7	Assignment Sheet EL-04c

AUDIOVISUAL(S)

A-1	Slide Set EL-04a
A-2	Slide Set EL-04b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet El-04a
L-2	Job Sheet EL-04b
L-3	Job Sheet EL-04c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

Assignment Sheet EL-04a

Provide an answer for the following questions and problems in the space provided. You may use the text assignment to refer to.

1. What is a series circuit?

2. Why does a control circuit connect its switches in series?

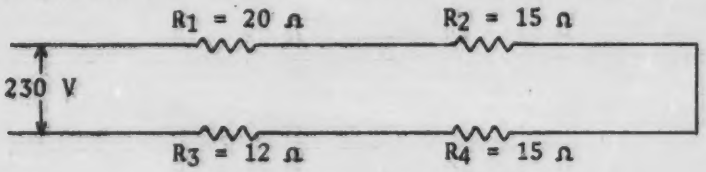
3. Draw a circuit with a switch ( ) and put it in series with a motor ( ).

4. Why is the current draw of a series circuit the same throughout the entire circuit.

5. A series circuit is composed of 5 resistors, each with a resistance of 2.7 ohms. What is the total resistance of the circuit?

6. Calculate the amperage of a series circuit that has a resistance of 5 ohms and a voltage of 120 volts.

7. Calculate the current of the following circuit.



I = _____

FIGURE A

8. What is the current and voltage drop across each heater in the following circuit?

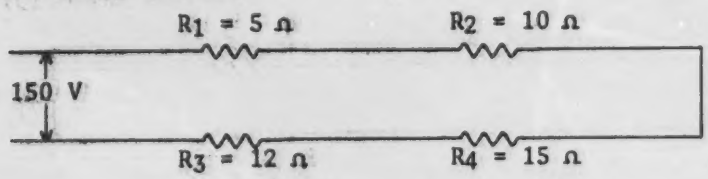


FIGURE B

The instructor will assign a wiring board on which the student should layout a series circuit. When the circuit is correctly laid out it should be wired and electrical readings made on the different components.

1. (A) Obtain wiring board #1. The board has four mounted light sockets wire the lights correctly in a series. Ask the instructor to check the circuitry before connecting the power and taking the readings. Install 4 cone heaters in sockets AB, CD, EF, & GH.

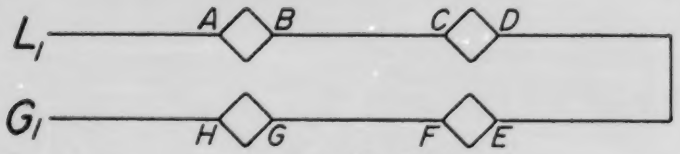


FIGURE C

(B) Measure and record on the following table the information requested. Do calculations on this page.

	MEASURED	CALCULATED
A. Voltage at L & G	_____	_____
B. Voltage at A & B	_____	_____
C. Voltage at C & D	_____	_____
D. Voltage at E & F	_____	_____
E. Voltage at G & H	_____	_____
F. Voltage at L & B	_____	_____
G. Voltage at L & D	_____	_____
H. Voltage at L & F	_____	_____
I. Voltage at L & H	_____	_____
J. Total Resistance	_____	_____
K. Total Amperage	_____	_____

2. Install a switch in series with a light bulb to control it.

3. Have the instructor check your work.

1. What is a parallel circuit?

2. How are parallel circuits utilzied in house wiring?

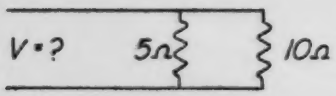
3. How are parallel circuits stabilized in house wiring?

4. Write the basic formula for amps, ohms, and voltage in a parallel circuit.

5. What is the total resistance of the following schematic of a circuit.

6. If the above four loads were connected in parallel to 230 volts, what would be the total amperage of the circuit?

7. Find the voltage of the following circuit.



8. What would be the KW rating of 4 electric heaters connected in parallel to a voltage of 230 volts if each heater had a resistance of 7 ohms?

The instructor will assign a wiring board to layout and wire a circuit in parallel. When the circuit has been wired check the components of the circuit and record the electrical readings.

(A). Obtain wiring board #2. Four light sockets should be mounted on the board. Connect the sockets correctly in parallel. Ask the instructor to check the board before connecting it to the power. Afterwards taking the measuremnts and install four cone heaters in sockets AB, CD, EF and GH.

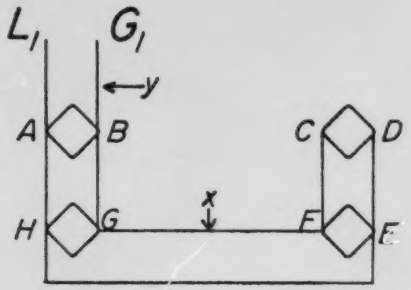


FIGURE D

(B). Measure and record the information on the following table.

	MEASURED	CALCULATED
A. Voltage at AB		
B. Voltage at HG		
C. Voltage at FE		
D. Voltage at CD		
E. Amperaged at Point X		
F. Amperate at Point Y		
G. Resistance of AB		
H. Total Resistance		
I. Total Amperage		

Series-Parallel Circuits

The series-parallel circuit is a combination of the series and parallel circuits. The electrical circuitry of most air conditioning equipment is composed of series-parallel circuits. An example of this is shown in the following diagram, (Figure E).

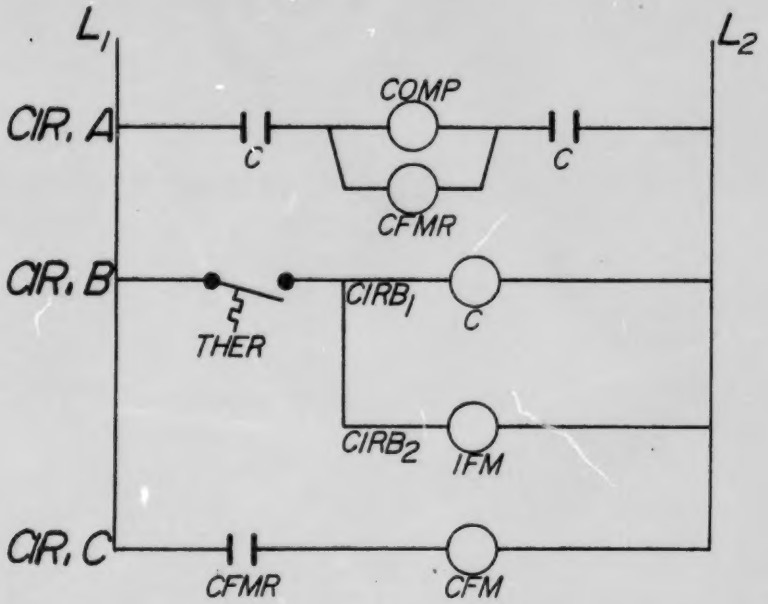


FIGURE E

Explanations of the circuitry in the diagram are as follows:

A. Circuits A, B & C are connected in parallel to L1 & L2.
B. CFMR in circuit A is parallel to compressor.
C. C contacts in circuit A is in series with COMP & CFMR.
D. In circuit B the THER is in series with circuits B1 & B2.
E. In circuit C the CFMR contacts are in series with the CFM.

1. Draw a series-parallel circuit to meet the following specifications.

   A. Circuit A - Two light bulbs in parallel controlled by one switch.
   B. Circuit B - One light bulb in series with switch.
   C. Circuit C - Three light bulbs controlled by one switch.

The instructor will assign a wiring board to layout and wire a series-parallel circuit. Connect a circuit which is similar to circuits in air conditioning equipment.

A. Obtain wiring board #3. The board consists of three switches controlling three light bulbs, wire these components correctly (See Figure F). Ask the instructor to check the layout and circuitry.

FIGURE F

B. Obtain wiring board #4. The circuits on the board are similar to many used in air conditioning equipment. Wire them correctly and ask the instructor to check the circuitry. (See Figure G).

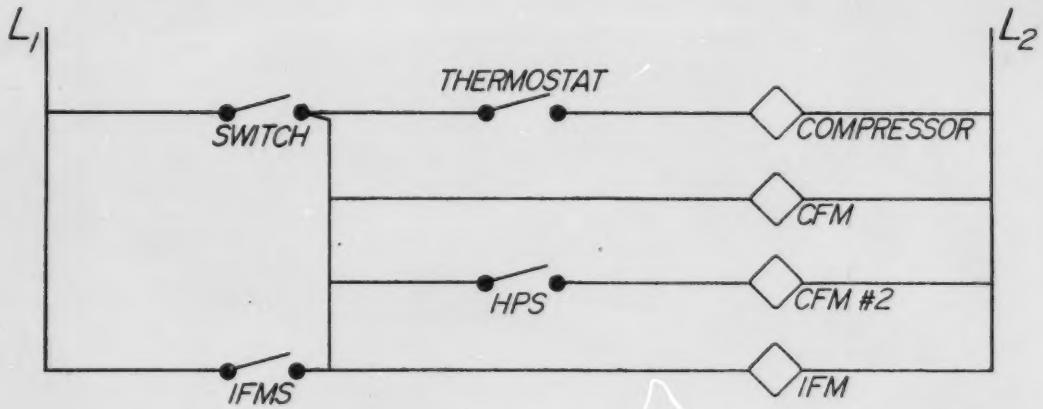


FIGURE G

MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Identifying Electrical Symbols **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-05

OBJECTIVE(S)

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-05a
W-2 Assignment Sheet EL-05a
W-3 Text Assignment El-05b
W-4 Assignment Sheet EL-05b
W-5 Text Assignment EL-05c
W-6 Assignment Sheet EL-05c
W-7 Text Assignment EL-05d
W-8 Assignment Sheet EL-05d
W-9 Assignment Sheet EL-05e
W-10 Assignment Sheet EL-05f
W-11 Assignment Sheet EL-05g

LABORATORY ASSIGNMENT(S)

L-1 _____
L-2 _____
L-3 _____
L-4 _____
L-5 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-05a
A-2 Slide Set EL-05b
A-3 Slide Set EL-05c
A-4 Slide Set EL-05d
A-5 _____
A-6 _____
A-7 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6 Instructor Check
C-7 Instructor Check
C-8 _____
C-9 _____

I. Answer the following questions:

1. What is a load?

2. What is an electric motor?

3. What is a solenoid?

4. Why would a signal light be used in an electrical circuit?

II. Identify the following symbols:

1.

2.

3.

4.

5.

6.

III. Draw the following symbols:

1. condenser for motor _____

2. compressor _____

3. three phase motor _____

4. red signal light _____

5. reversing valve solenoid _____

6. supplementary heater _____

I. Answer the following questions:

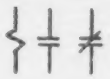
1. What is the difference between a contactor and a relay?

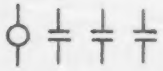
2. What do the terms "normally open" and "normally closed" refer to?

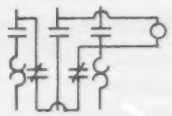
3. What is the difference between a magnetic starter and a contactor?

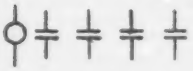
II. Identify the following symbols:

1.

2. 

3. 

4. 

5. 

III. Draw the following symbols:

1. 3 pole contactor _____

2. relay with 2 N.O. and 2 N.C. contacts _____

3. magnetic starter _____

4. relay with 1 N.C. contact _____

5. 2 pole contactor _____

I. Answer the following questions:

1. Why are heating and cooling thermostats different?

2. What is a disionent switch?

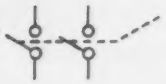
3. What is a pressure switch?

4. Why is a push button switch used?

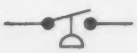
II. Identify the following symbols:

1.

2.

3. 

4.

5. 

6.

7.

8.

III. Draw the following symbols:

1. pressure switch (opens on rising pressure) _____

2. heating thermostat _____

3. N.O. push button _____

4. 3 pole disconnect switch _____

5. SPST switch _____

6. DPDT switch _____

7. cooling thermostat _____

8. pressure switch (close or rising pressure) _____

I. Answer the following questions:

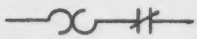
1. What is the purpose of a fuse?

2. What is the purpose of an overload?

3. What is the difference between a thermal type and magnetic type overload?

II. Identify the following symbols:

1.

2. 

3.

4.

5.

6.

III. Draw the following symbols:

1. magnetic overload _____

2. fuse _____

3. transformer _____

4. in line thermal overload _____

5. thermal overload relay _____

1. Draw the correct symbol for the following components:

   a. 3 pole contactor _____

   b. 3 ϕ compressor motor _____

   c. transformer (w/dual voltage line voltage side) _____

   d. heating thermostat _____

   e. capacitor _____

   f. thermal overload relay _____

   g. high pressure switch _____

   h. relay w/3 N.O. contacts _____

   i. 3 pole disconnect switch fuse _____

   j. fuse _____

   k. magnetic starter _____

   l. red signal light _____

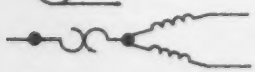
   m. push button N.O. _____

   n. time delay relay _____

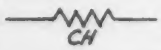
   o. relay w/2 N.O. and 2 N.C. contacts _____

2. Label the following symbols:

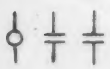
   a.

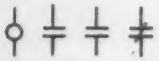
   b. 

   c.

   d. 

   e.

   f. 

   g. 

   h.

   i.

   j.

   k.

   l.

   m.

   n.

   o.

A. How many of the following devices are in Figure A?

1. motors _____
2. heating thermostats _____
3. cooling thermostats _____
4. transformer _____
5. low pressure switch _____
6. high pressure switch _____
7. time delay relays _____
8. fuses _____

B. Answer the following questions from Figure A.

1. How many line voltage legs are installed with overload going to compressor #2?

2. How many contacts does the CR have and what are their positions?

3. What type of switching device is WSR 1?

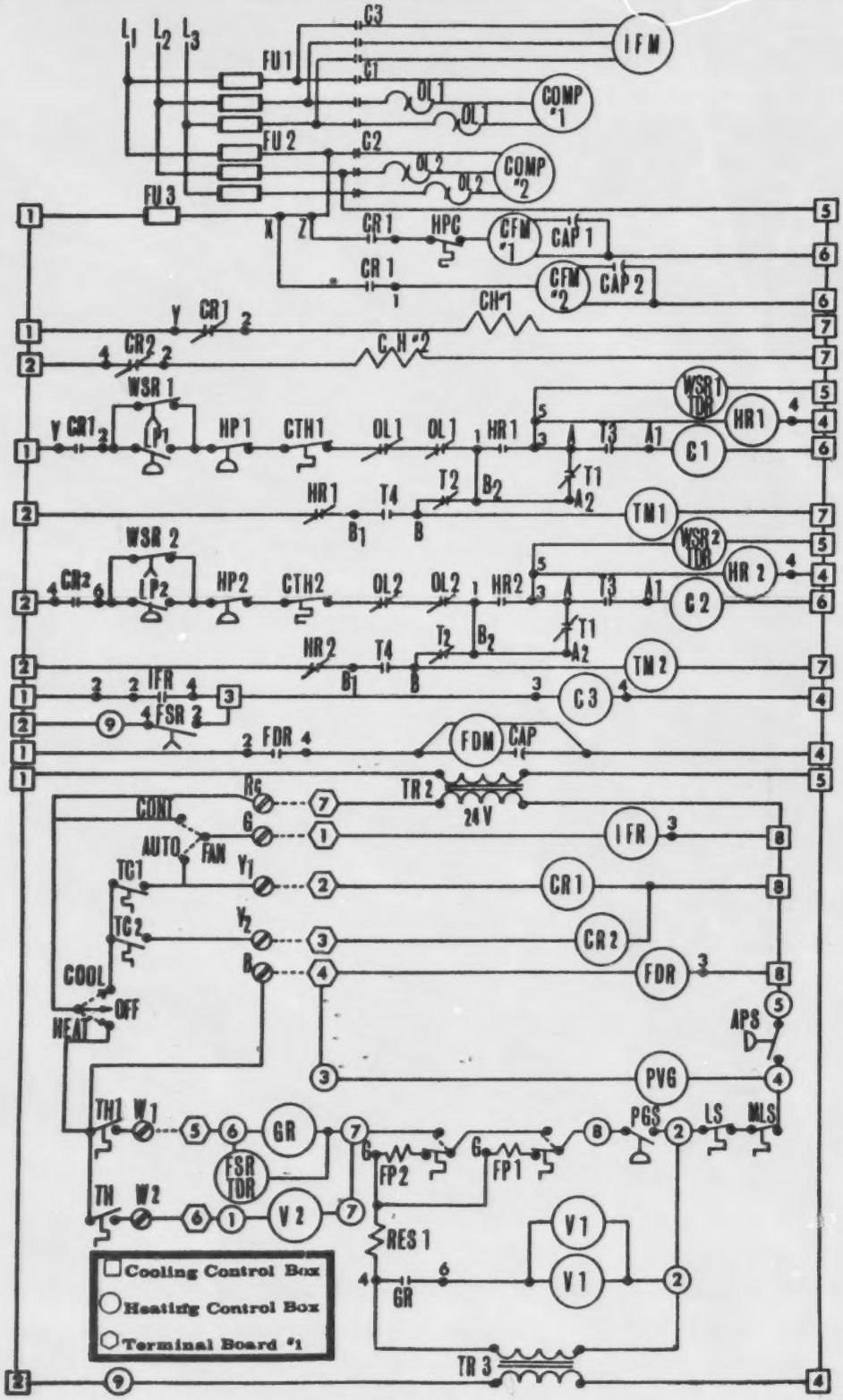

L1 L2 L3
FU1
FU2
FU3
C3
C1
C2
IFM
COMP #1
COMP #2
OL1
OL2
CR1
HPC
CFM #1
CFM #2
CAP 1
CAP 2
CH #1
CH #2
CR2
WSR 1
WSR 2
HP1
HP2
CTH1
CTH2
HR1
HR2
T1
T2
T3
T4
TM1
TM2
C1
C2
C3
IFR
FSR 2
FDR
FDM
CAP
TR2
24V
CONT
AUTO
FAN
TC1
TC2
COOL
HEAT
OFF
Rc
G
Y1
Y2
R
APS
PVG
TH1
W1
GR
FSR TDR
TH
W2
V2
V1
RES 1
FP2
FP1
PGS
LS
MLS
TR3
Cooling Control Box
Heating Control Box
Terminal Board #1

FIGURE A

A. Answer the following questions using Figure B.

1. What type of overload is used to protect the compressor motor?

2. If the transformer on the left side of the diagram is used, what is the supply voltage to the unit?

3. What is the purpose for 3 wires (black, red and blue) being used on line voltage side of the low voltage transformer?

4. What is IH in the wiring diagram?

5. How many sets of contacts does the lock out relay have and what are their positions?

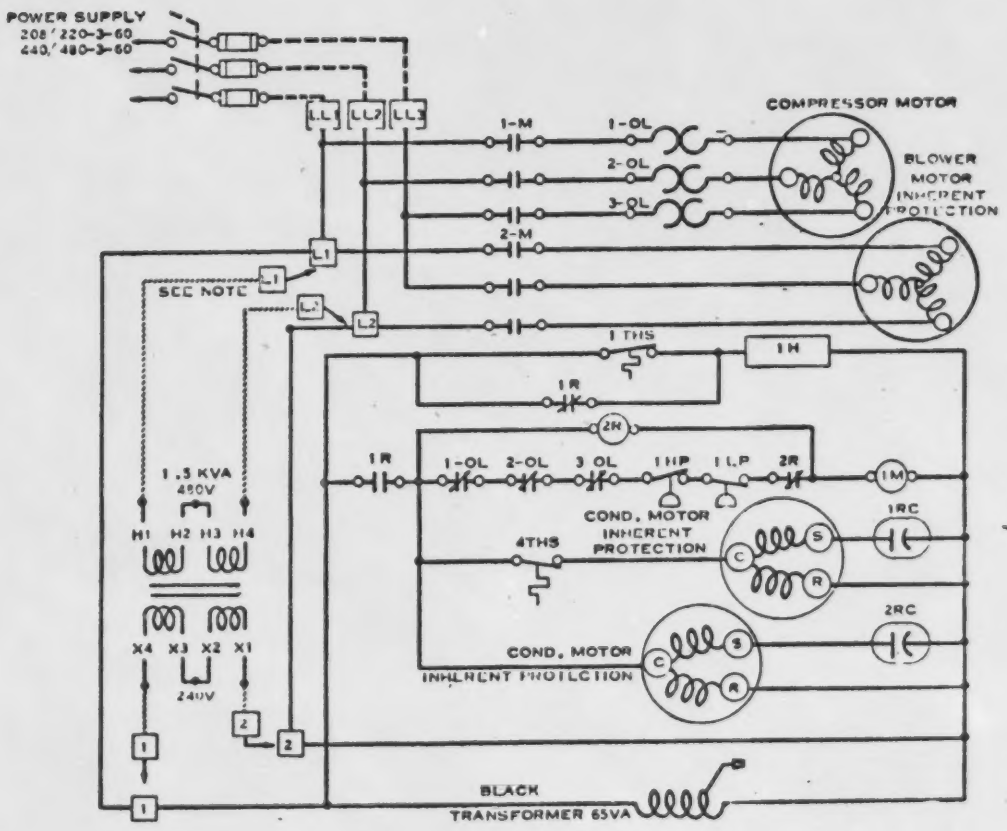


FIGURE B

MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Reading a Basic Schematic Diagram **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-06

OBJECTIVE(S) Read and interpret Schematic Diagrams.

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-06a
W-2 Assignment Sheet EL-06a
W-3 Text Assignment EL-06b
W-4 Assignment Sheet EL-06b
W-5 Text Assignment EL-06c
W-6 Assignment Sheet EL-06c
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-06a
A-2 Slide Set EL-06b
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-06a
L-2 _____
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 _____
C-3 _____
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Answer the following questions:

1. How is a pictoral diagram laid out?

2. What is a legend in a schematic diagram?

3. What is a factual diagram?

4. How is a schematic diagram laid out?

Answer the following questions about the diagram in text assignment EL-06b

1. How many line voltage loads are shown in the diagram? Name them.

2. What controls the IFM and how?

3. How does the contactor control the compressor and condenser fan motor?

4. What would happen if the HPS opened while the compressor was operating?

5. What type of thermostat is used in the control system?

6. If the fan switch on the thermostat is in the ON position; will the fan cut on when the thermostat closes?

I. Answer the following questions about the diagram (Figure 3-38 on page 63,) examined in Text Assignment REW-06c.

1. How many line voltage loads are shown in the diagram? Name them.
2. What would happen if the high pressure switch opened while the compressor was operating?
3. The HP and LP are connected in (Series, parallel) with the compressor.
4. Which load does relay IFR control?
5. Which switch opens or closes the circuit to the contactor coil "M" during automatic operation?
6. Mark the following statements true or false.

_____a. When contacts "M" are closed the compressor will operate

_____b. The On-Auto switch is in the ON position, the IF is operating.

_____c. The transformer is faulty, the contactor will close and operate the compressor.

_____d. The fuse on line one is open, the IF will not be affected.

_____e. The On-Auto switch is in the auto position, the cooling thermostat is closed, the IF will not operate.

7. Write an operational sequence of the control system.

II. Answer the following questions from figure 12.3, page 261, text #1.

1. What would happen if the SR coil was bad?
2. What would be the results if the HPS opened?

3. What controls the fan motor?

4. What type of overload does the compressor have?

5. Mark the following statements true or false.

   _____a. The FM is a two speed electric motor.

   _____b. The FM is operated by the FR on the cooling cycle operation.

   _____c. If the internal overload in the compressor opens, the contactor will be de-energized.

6. Write an operational sequence of the control system in the diagram.

I. Draw a schematic diagram to meet the following specifications.

SPECIFICATIONS

1. UNIT TYPE: Window air conditioning
2. COMP TYPE: PSC motor
3. FAN MOTOR TYPE: PSC motor (single speed)
4. Thermostat
5. Fan motor to operate when compressor runs only

II. Draw a schematic diagram to meet the following specifications.

SPECIFICATIONS

1. UNIT TYPE: Condensing unit (only)
2. COMP TYPE: PSC motor with internal overload
3. CFM TYPE: PSC motor
4. 24-volt control system
5. LP and HP switch to protect compressor
6. Show wiring of condensing unit only, do not show transformer or thermostat.

MAJOR BLOCK Electricity **NAME** _____

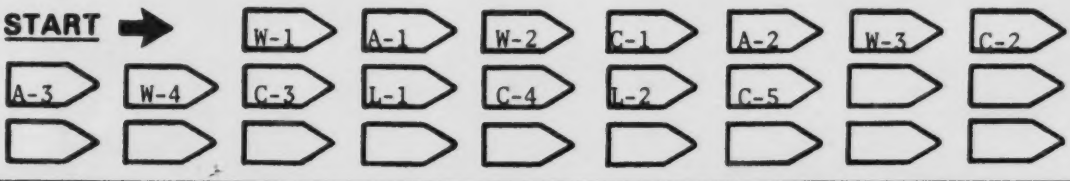
TASK Fundamentals

UNIT Reading an Advanced Schematic Diagram **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-07

OBJECTIVE(S)

Demonstrate an ability to correctly read an advanced schematic diagram.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-07a
W-2 Assignment Sheet EL-07a
W-3 Assignment Sheet EL-07b
W-4 Assignment Sheet EL-07c
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-07a
A-2 Slide Set EL-07b
A-3 Slide Set EL-07c
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-07a
L-2 Job Sheet EL-07b
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Reading the Advanced Schematic

Answer the following questions from Figure A.

1. How many line voltage "load" circuits are shown in the diagram?

2. How many low voltage "load" circuits are shown in the diagram? Name them.

3. What relay controls the outdoor fan motor?

4. What two switches must be closed to energize the compressor relay coil?

5. When the compressor relay coil is energized, how many switches will change position? What position will they change to, opened or closed? Will they complete the circuits to any loads? If so, name them.

6. With the "Auto-On" switch in the "On" position, what effect will the closing of the thermostat have on the indoor fan relay?

7. How many sets of contacts in the switch controlled by the coil "C"? What is their normal position?

8. With the "Auto-On" switch in the "Auto" position, the indoor fan will start before the outdoor fan. (True or False)

9. What operates the switch labeled "Cool"?

10. Not counting the fused disconnect switch, how many switches are in line to the compressor?

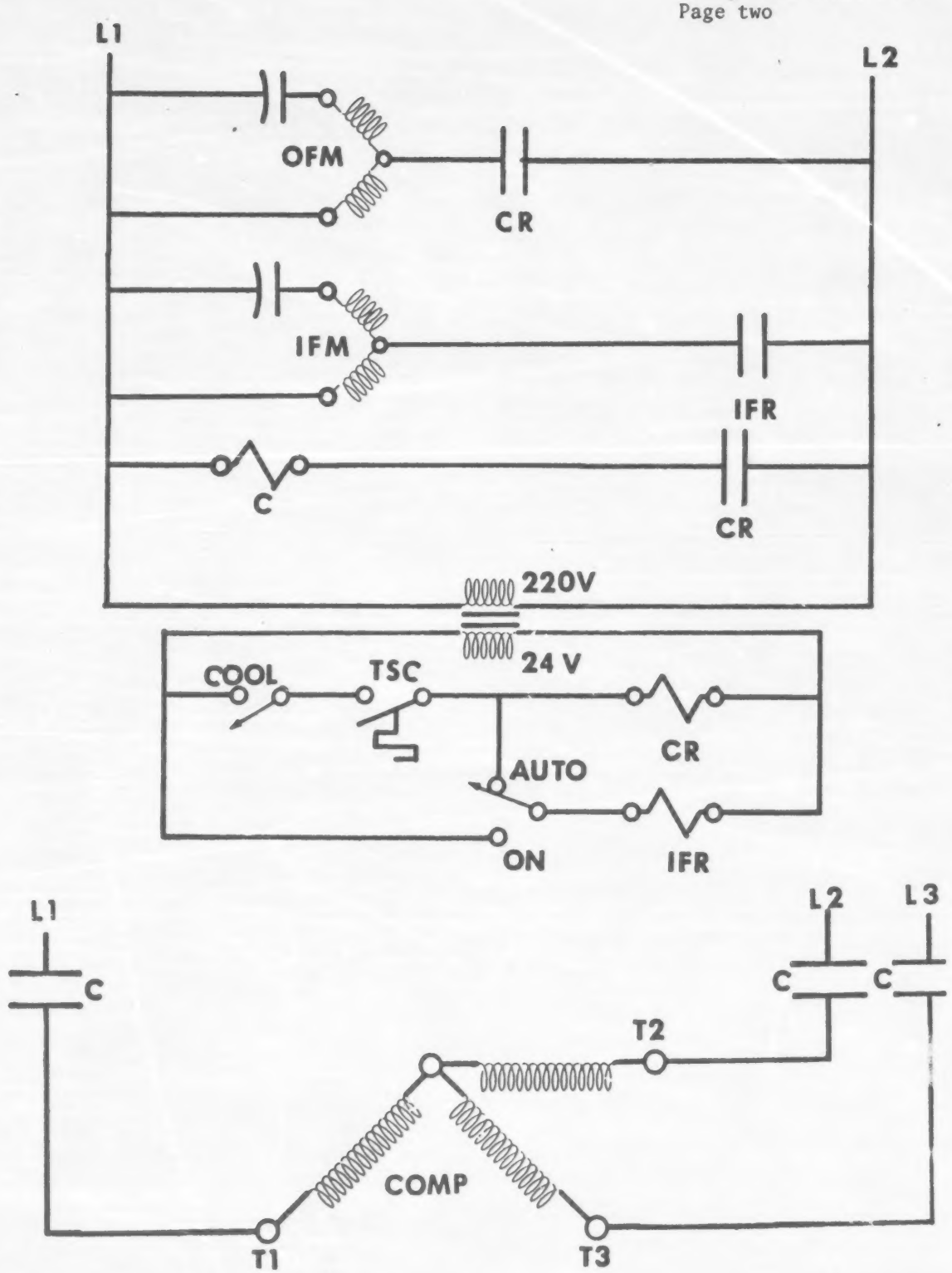

L1
L2
OFM
CR
IFM
IFR
C
CR
220V
24 V
COOL
TSC
CR
AUTO
ON
IFR
L1
C
L2
L3
C
C
T2
COMP
T1
T3

FIGURE A

Answer the following questions from Figure B.

1. How many sets of contacts are on the reversing valve relay?

2. How many loads are in the same circuit(s) with the contact(s)? Name them.

3. What switches must be closed to energize the first resistance heater contactor coil?

4. What forces close the switch (s) in #3 above?

5. What determines the number of resistance heaters that are turned on when the second step of the heating thermostat closes?

6. Assuming all switches are set properly and all load devices functioning satisfactorily, is it possible to turn on the number three (3) strip heater without turning on number one (1)?

7. Assuming all switches are correctly set and all load devices are functioning properly, in the diagram shown, is it possible to operate the number one strip heater without compressor operation?

8. With the manual fan switch in the position shown, the unit heat switch closed, what effect will closing the first step of the heating thermostat have on the indoor fan motor?

9. With the manual fan switch settings satisfactory and all loads functioning properly, with the manual switch in the "Heat" position, the first step of the thermostat closes. Describe the step by step electrical action until all four (4) required loads to heat are properly functioning.

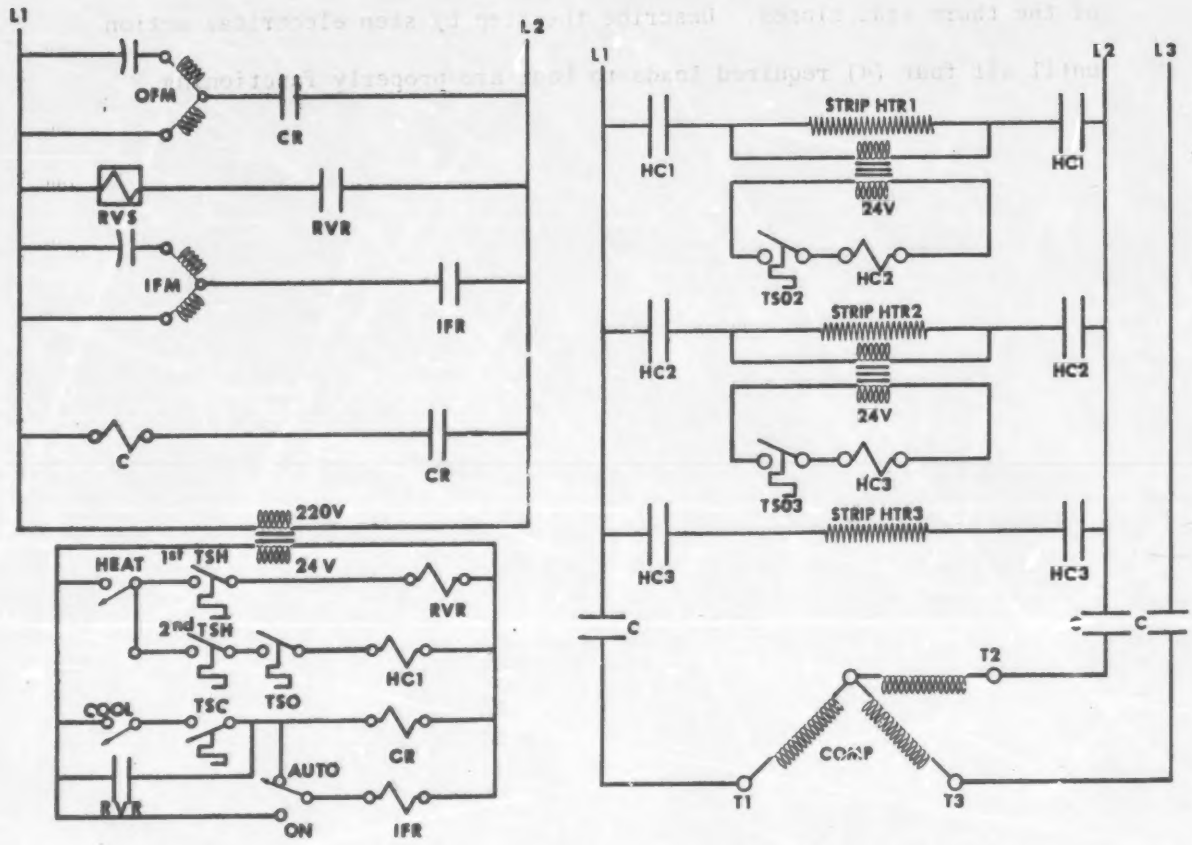

L1
L2
OFM
CR
RVS
RVR
IFM
IFR
C
CR
220V
HEAT
1st TSH
24 V
RVR
2nd TSH
HC1
TSC
TSO
COOL
CR
AUTO
RVR
ON
IFR
L1
L2
L3
STRIP HTR1
HC1
HC1
24V
HC2
TSO2
STRIP HTR2
HC2
HC2
24V
HC3
TSO3
STRIP HTR3
HC3
HC3
C
C
T2
COMP
T1
T3

FIGURE B

Answer the following questions from Figure C

1. What switch(s) are in the reversing valve solenoid circuit and what are (is) their normal position?

2. If the contactor coil does not energize when the compressor relay coil is energized, how many switches could be checked? Name them.

3. What switch(s) are in the defrost relay coil circuit?

4. How many switches does the defrost relay have? What are their normal positions?

5. The first step heating thermostat is closed, the second step is not. The unit goes on the defrost cycle and the first strip heater unit comes on. Can this be correct? If so, how does the heater become energized with the 2nd step of the heating thermostat open?

6. What is the purpose of the time delay relay?

7. With the compressor and all three strip heaters in operation the "Klixon" for the first strip heater contactor opens due to overheating. What happens to the remaining two strip heaters?

8. From an examination of the diagram, what would the air pressure have to do to close the air pressure switch (AS), increase or decrease?

9. The overload in the L_2 circuit to the compressor opens during operation. How does this stop the compressor? If all strip heaters are "on" at the time, will they be turned "off"?

10. Upon arriving on a job, the compressor and #1 and #3 strip heaters are operating. The unit is wired correctly. Where is the problem?

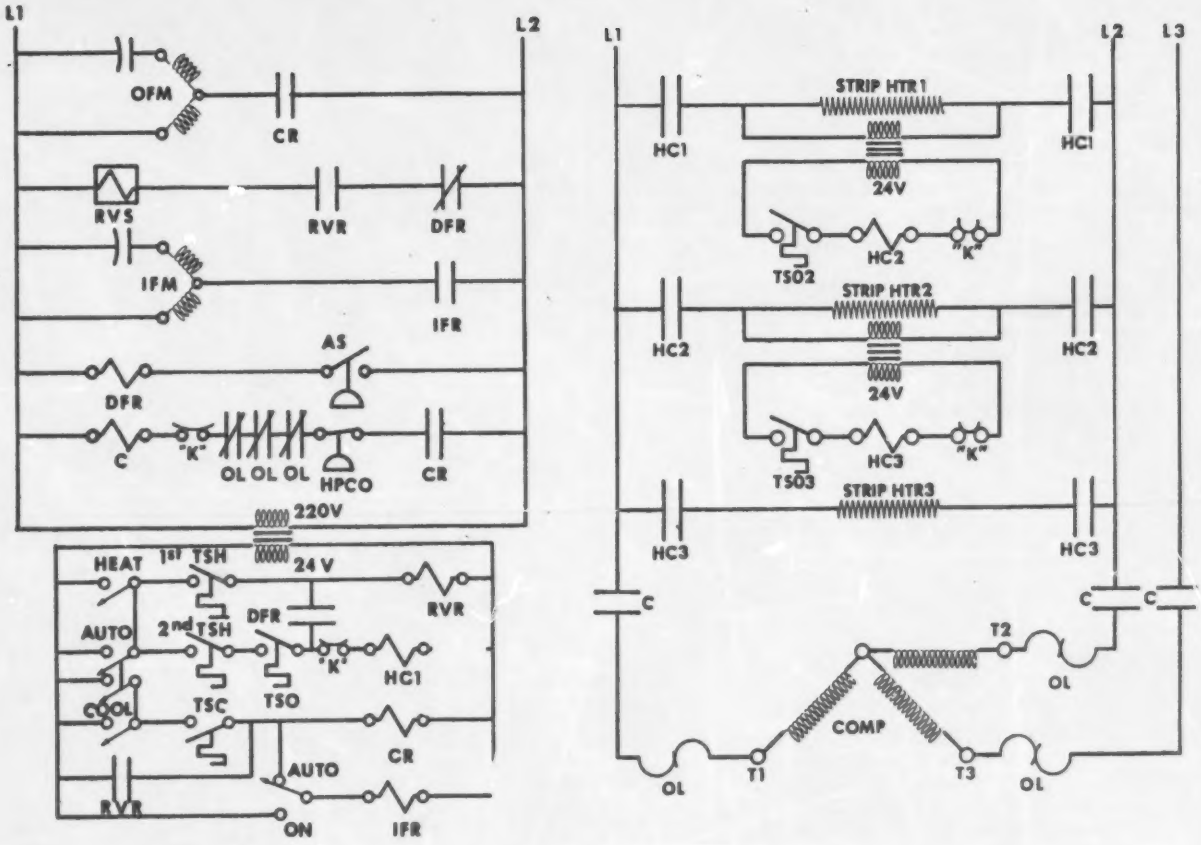

L1
L2
OFM
CR
RVS
RVR
DFR
IFM
IFR
AS
DFR
C
"K"
OL OL OL
HPCO
CR
220V
HEAT
1st TSH
24 V
RVR
AUTO
2nd TSH
DFR
"K"
HC1
COOL
TSC
TSO
CR
AUTO
RVR
ON
IFR
L1
L2
L3
STRIP HTR1
HC1
HC1
24V
TSO2
HC2
"K"
STRIP HTR2
HC2
HC2
24V
TSO3
HC3
"K"
STRIP HTR3
HC3
HC3
C
C
C
T2
OL
COMP
OL
T1
T3
OL

FIGURE C

1. Write operational sequence of unit from Diagram D.

2. Diagnose the following problems:

FIGURE D

1. Complaint: No Cooling

   a. indoor fan motor operating
   b. compressor is good, but not operating
   c. switch is good
   d. thermostat, pressurestat, and klixon closed
   e. contactor coil good

2. Complaint: No Cooling

   a. indoor fan motor operating
   b. compressor is good, but not operating
   c. switch is good
   d. discharge pressure 185 psig
   e. suction pressure 22 psig

FIGURE E

3. Complaint: Intermittent Cooling

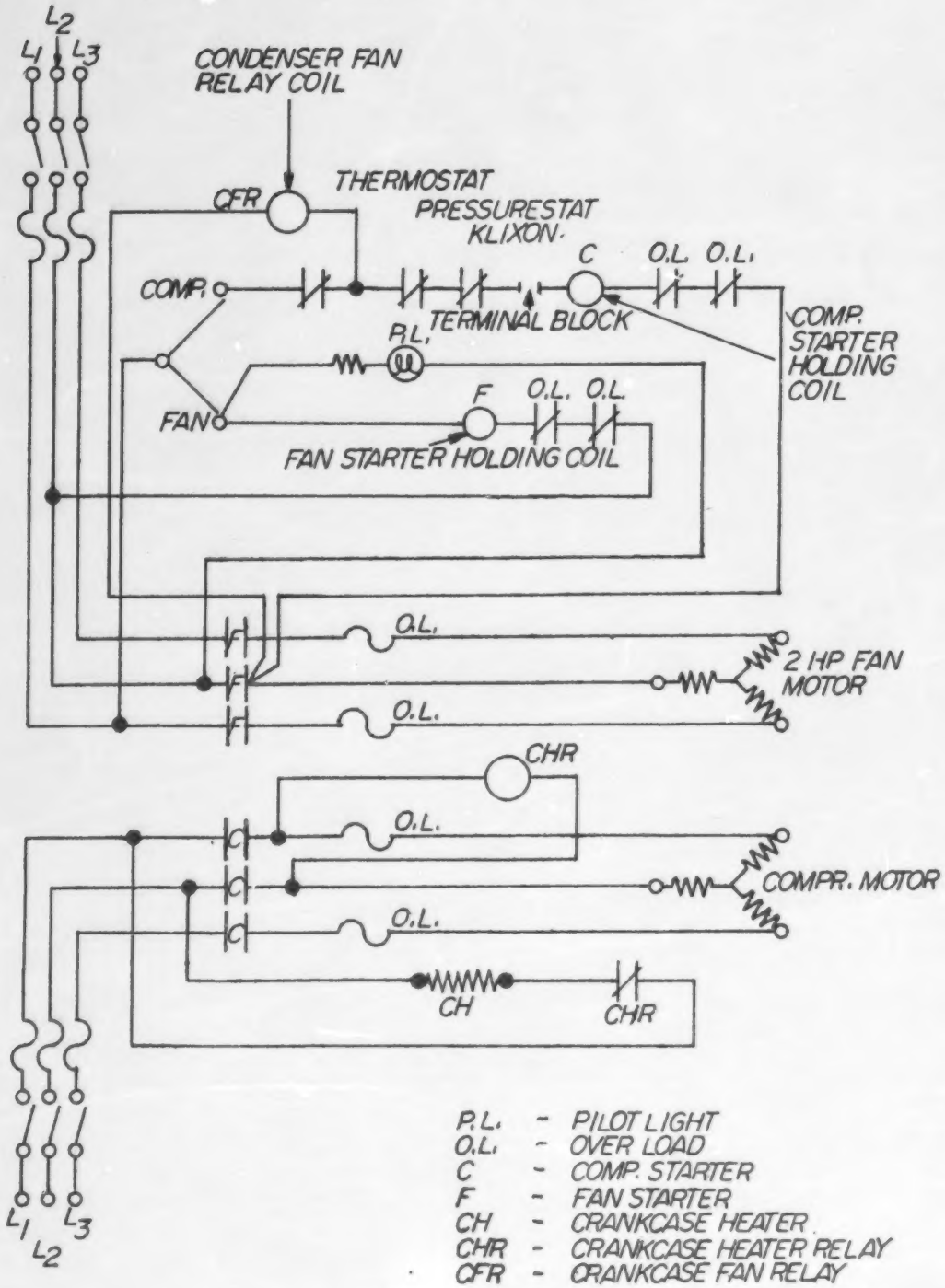
   a. occasion interruption of compressor operation
   b. hp 345 psig
   c. LP 60 psig
   d. one OFM operating
   e. second OFM good

4. Complaint: No Heating

   a. flame is proved
   b. IBM will not run
   c. IFR good
   d. IFM good

5. Complaint: Insufficient Heating

   a. flame is proved
   b. all unit components are good



P.L. - PILOT LIGHT
O.L. - OVER LOAD
C - COMP. STARTER
F - FAN STARTER
CH - CRANKCASE HEATER
CHR - CRANKCASE HEATER RELAY
CFR - CRANKCASE FAN RELAY

FIGURE D

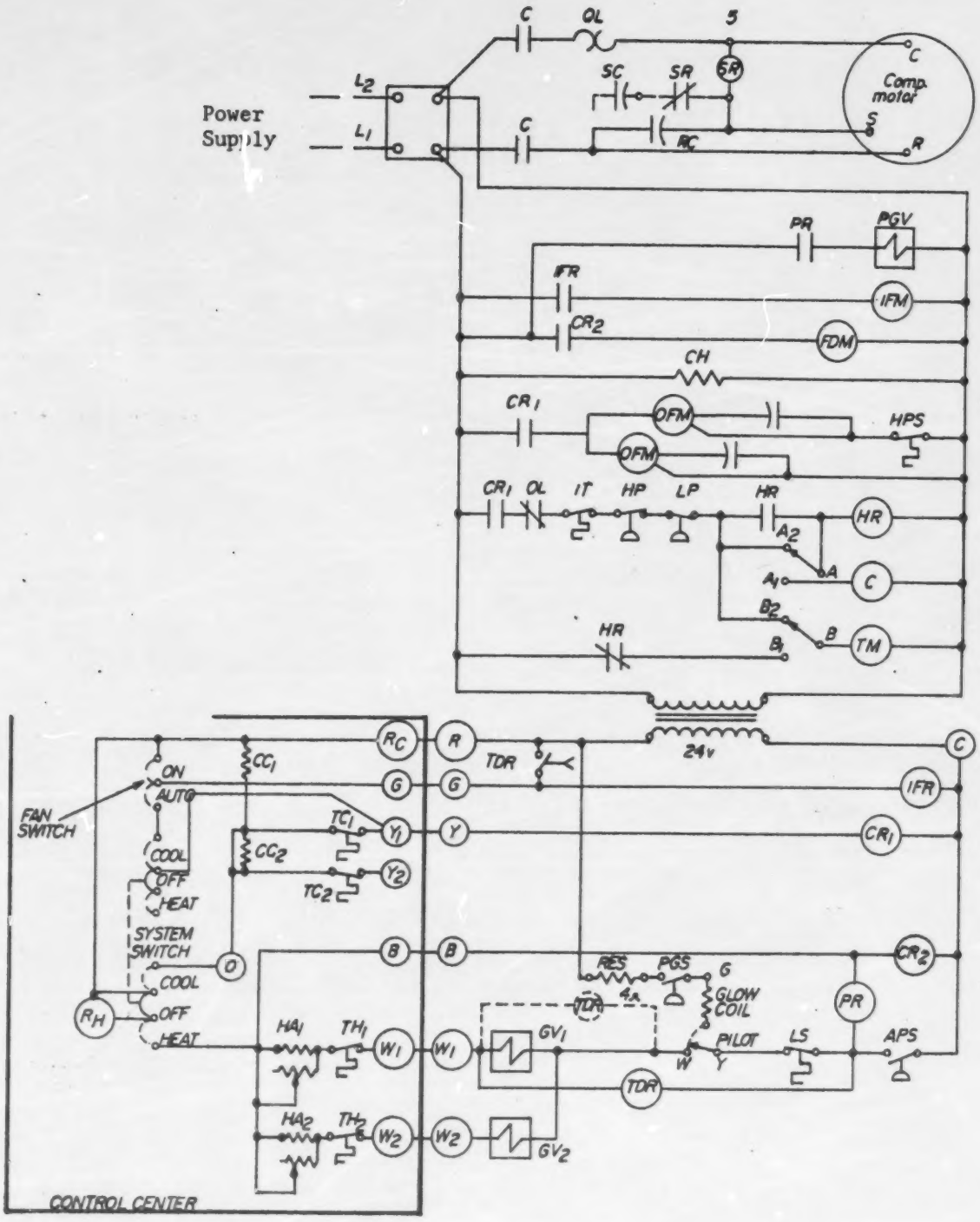

Power Supply
L2
L1
C
OL
S
SC
SR
RC
Comp. motor
PR
PGV
IFR
IFM
CR2
FDM
CH
CR1
OFM
HPS
OL
IT
HP
LP
HR
A2
A1
A
C
B2
B1
B
TM
24v
FAN SWITCH
ON
AUTO
COOL
OFF
HEAT
CC1
CC2
TC1
TC2
SYSTEM SWITCH
RH
HA1
TH1
HA2
TH2
W1
W2
GV1
GV2
TDR
RES
PGS
GLOW COIL
PILOT
LS
APS
CONTROL CENTER

FIGURE E

1. Draw a wiring diagram with the following components.
   a. 460v-3-to power supply
   b. part winding compressor
   c. 110 volt control circuit
   d. pump down cycle with two liquid line solenoids
   e. three condenser fan motors with head pressure control
   f. 24 volt thermostat with two stg cool
   g. IFM operating constant
   h. five minute timer to prevent short cycling

NOTE: MAKE THE SYSTEM AUTOMATIC OTHER COMPONENTS WILL HAVE TO BE ADDED. USE FIGURES 12.66 on PAGE 265 (SCHEMATIC OF A PART WINDING MOTOR HOOKUP) AND FIGURE 3.47 ON PAGE 69 (SCHEMATIC DIAGRAM OF A LARGE COMMERCIAL AND INDUSTRIAL CONDENSING UNIT) IN TEXT 3.

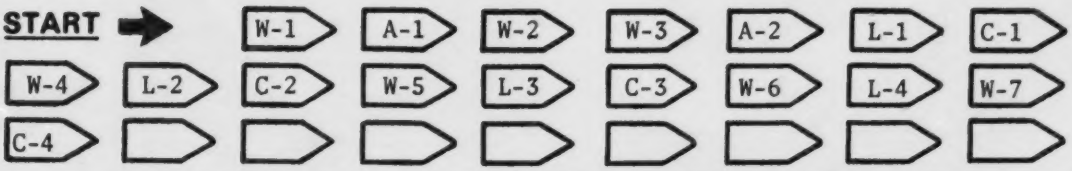
MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Alternating Current Principles **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-08

OBJECTIVE(S) Demonstrate a knowledge of alternating current principles



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-08a
W-2	Assignment Sheet EL-08a
W-3	Text Assignment EL-08b
W-4	Text Assignment EL-08c
W-5	Text Assignment EL-08d
W-6	Text Assignment EL-08e
W-7	Assignment Sheet EL-08b

AUDIOVISUAL(S)

A-1	Slide Set EL-08a
A-2	Slide Set EL-08b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-08a
L-2	Job Sheet EL-08b
L-3	Job Sheet EL-08c
L-4	Job Sheet EL-08d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Answer the following questions:

1. What is alternating current?

2. What is the frequency of alternating current?

3. What is the most common frequency of an alternating current in the United States?

4. What is the difference between single and three phase alternating current?

5. What is reactance?

6. What is impedance?

7. What is the power factor?

1. Draw a power distribution system from electrical source at 4600 volts to a sub-station (lowers voltage to 2300 volts) to a transformer (lowers voltage to 460v) to a structure.

1. Measure the voltage of a 230v-1Ø-60hz voltage system and identify the ground and the hot legs.
2. Make connections in the panel to obtain 230v-1-60 and 115-1-60 cycles.

1. Measure the voltage of Delta (230v-3Ø-60hz) and the WYE (208-3-60) voltage systems and identify the ground, hot legs, and high leg (of 230-3-60).
2. Make connections in the panels to obtain 208-3-60 and 230-3-60.

1. Measure the voltage of a 460v-3-60 system. Identify the ground and hot legs.
2. Make connections in the panel to obtain 460v-3-60.

SAFETY NOTE: BE ESPECIALLY CAREFUL WHEN HANDLING HIGHER VOLTAGES.

Answer the following questions:

1. What is the advantage of 3 phase over single phase current?

2. What is impedance?

3. What is reactance?

4. What is the most common electrical service supplied to residences in the United States?

5. What is the voltage supplied by a "delta" transformer hookup?

6. What is the voltage supplied by a "Wye" transformer hookup?

7. What are the advantages and disadvantages of using a higher voltage system?

8. Explain the 277/480 volt system.

MAJOR BLOCK Electricity **NAME** _____

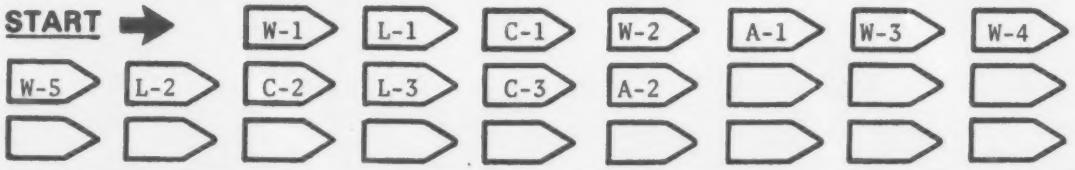
TASK Fundamentals

UNIT Determining, Selecting Wire Size and Making Connections **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-09

OBJECTIVE(S)

Determine wire size and type per ampacity.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-09a
W-2	Text Assignment EL-09b
W-3	Assignment Sheet EL-09a
W-4	Text Assignment EL-09c
W-5	Assignment Sheet EL-09b
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-09a
A-2	Slide Set EL-09b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-09a
L-2	Job Sheet EL-09b
L-3	Job Sheet EL-09c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

1. Obtain 10 samples of wire from wire supply, noticing each size and insulation type when cutting it from the roll. Do not cut more than 1 inch.
2. Obtain from the instructor 20 pieces of wire, examine each, and complete the data sheet below.

Wire Sample	AWG Size	Insulation Type	Use
#1			
#2			
#3			
#4			
#5			
#6			
#7			
#8			
#9			
#10			
#11			
#12			
#13			
#14			
#15			
#16			
#17			
#18			
#19			
#20			

Assignment Sheet EL-09a

Answer the following questions from the National Electric Code.

1. Define:

   a. appliance

   b. automatic

   c. branch circuit, individual

   d. bonding

   e. circuit breaker

   f. concealed

   g. enclosure

   h. grounding conductor

   i. overload

   j. nominal voltage

2. What is the largest allowable wire size where a solid conductor can be used in a raceway?

3. What is the largest resistance type heating element that can be used without subdividing?

4. When can a thermostat be permitted to serve as the controller and disconnecting means?

5. Should a duct heater have some type of fan interlock? Why?

6. How should electric motors be marked?

7. How should a single motor brand circuit be sized?

8. How should a hermetic compressor be marked?

9. What is permitted as the disconnecting means of cord connected appliance?

10. How is a branch circuit conductor sized for a unit with more than one motor?

Assignment Sheet EL-09b

1. Using the NEC, determine the correct size for the ampacity listed.

	AMPACITY	WIRE SIZE	TYPE INSULATION
1.	100A		
2.	65A		
3.	15A		
4.	40A		
5.	200A		
6.	25A		
7.	20A		
8.	135A		
9.	50A		
10.	150A		

1. See instructor for assignment to two air conditioning units.

2. Size wire using manufacturers installation instructions for two air conditioners.

SIZE & TYPE OF WIRE

A/C #1

A/C #2

1. See instructor for assignment to two air conditioning units.

2. Size wire for two air conditioners from the National Electric Code.

SIZE & TYPE OF WIRING

A/C #3

A/C #4

MAJOR BLOCK Electricity **NAME** _____

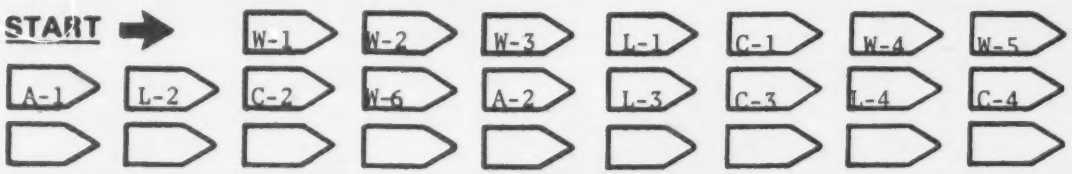
TASK Fundamentals

UNIT Making Main Panel Connections **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-10

OBJECTIVE(S)

Make a main panel connection for an air conditioner.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-10a
W-2 Information Sheet EL-10a
W-3 Text Assignment EL-10b
W-4 Information Sheet EL-10b
W-5 Assignment Sheet EL-10a
W-6 Assignment Sheet EL-10b
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-10a
A-2 Slide Set EL-10b
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-10a
L-2 Job Sheet EL-10b
L-3 Job Sheet EL-10c
L-4 Job Sheet EL-10d
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Fuses and Sizes

The simplest and most widely used method of overcurrent protection is the fuse. They are used in almost all phases of the industry. The cartridge fuse is the most popular type of fuse used. The fuse is available in standard ampere rates from 15 to 6000, with the common size for this industry being 15A to 200A.

Fuses vary in physical size; for example, the 250 volt fuse is smaller than the 600 volt fuse. There are many special application fuses which also vary in physical size. The normal 250 volt fuses have certain common sizes, for example any fuse from 15 to 30 amps is the same size. The 35 amp to 60 amp fuses are the same size as well as 70 amp to 100 amp and also from 125 amps to 200 amps.

A 30 amp disconnect switch is used to house any fuse of that same physical size and the same applies to a 60 amp, 100 amp and 200 amp disconnect.

Circuit breakers are in wide use in the industry and are available in most of the same sizes as fuses. For sizing fuses or breakers refer to the NEC.

1. Size disconnect switch for condensing unit.
2. Install disconnect switch on condensing unit.
3. Install wiring from power source to disconnect to condensing unit.

(Reprinted through the courtesy of Furnas Electric Co., Batavia, Illinois.)

Information Sheet EL-10b

SAFETY SWITCHES

CLASS 73

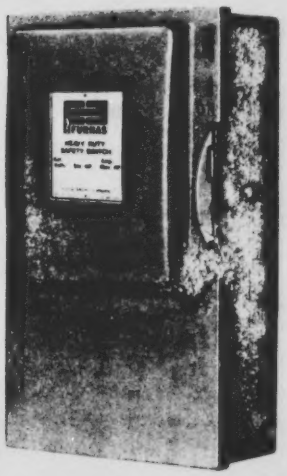
HEAVY DUTY

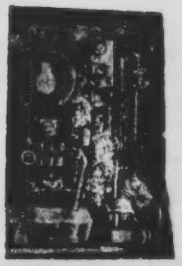
Series 73HA Heavy Duty Safety Switches are designed for use on inductive and resistive loads up to 600 volts A-C or 250 volts D-C. Listed with Underwriters' Laboratories and built in accordance with NEMA standards, they are especially suited for such heavy industry applications as steel mills, railroads and paper mills, Three different enclosures are available to meet specific application requirements.

Heavy duty safety switches are available as fused or non-fused (disconnect) type, 30 through 600 amperes, in NEMA 1, 3R, and 12 encloures. The tease-proof switching mechanism is "quick-make, quick-break," can be operated independently of the drive spring. Neutral bars are insulated with a grounding terminal and screw for connecting the neutral to the enclosure included. Enclosures for switches through 200 amperes are drilled and tapped to accommodate type J fuses. Unfused switches are dual voltage rated for application on 240 or 600 volt circuits with corresponding horsepower ratings.

Electrical interlock kits are available for heavy duty safety switches. The kit contains a contact block having 1 NO and 1 NC contact rated 10 amps resistive and 6 amps inductive, mounted on a steel bracket with a control arm. The control arm is actuated by the switch mechanism and breaks the control circuit before the safety switch opens.

NEMA 1





Optional Electrical Interlock

Enclosures

NEMA 1: Used for industrial applications where the atmosphere is reasonably clean and dry. Of sheet steel with bonderized finish, has knockouts and front-operable interlock defeater in ratings through 200 amperes.

NEMA 3R: Suitable for outdoor applications where unit will be completely exposed. Cover is hinged at top, is "locked" open by drip shield. Of galvannealed steel with bonderized finish, knockouts are located at load end below terminals with interlock defeater on the right side. Mounting holes are embossed to keep enclosure away from mounting surface. Top shield has provision for hubs ¾" through 3".

NEMA 12: Use on applications where coolants, oil, lint, dust and other foreign matters will be encountered. Meets UIC requirements, has no knockouts or other openings. Sheet steel with bonderized finish, it has exterior mounting feet. Door has neoprene gasket, screw down fasteners and interlock defeater on side of enclosure.

NEMA 1 Enclosure Features

- **Arc Chute:** Extinguishes hot arcs by dividing and cooling them quickly.
- **Diamond Pointed Jaws:** Lead breaking arc along non-current carrying surfaces of jaw and moving blades; prevents burning and pitting of current carrying surfaces.
- **Visible Blades:** Blade position easily determined.
- **Fuse Holders:** Easily accessible for fuse removal, replacement; holders are reinforced.
- **Door Latch:** Holds door closed, permits padlocking door in closed position. Latch must be engaged before switch blades can be closed.
- **Dual Cover Interlock:** Prevents opening cover unless switch is OFF; switch cannot be thrown ON when door is open. Both conditions can be defeated by using a screw driver in the slot on the door above the handle.
- **Line Terminal Shield:** Arc chute prevents contact by operating personnel.
- **Operating Mechanism:** is non-teasable; provides positive "quick-make, quick-break" operation; handle operates independently of cam and cross bar, can be closed or opened even though drive spring may be broken.
- **Operating Handle:** Heavy duty switches have front operated handles, can be ganged without hindering operation; handle is part of and is always in control of switch mechanism; red vinyl cover identifies handle, indicates position at all times.
- **Copper/Aluminum Terminals:** Either copper or aluminum wire can be used on both line and load terminals

Wiring Area: Adequate wiring room has been provided on all switches.

Knockouts: Ample knockouts have been provided as shown above.

Mounting Holes: Keyhole slots at enclosure top, regular holes at bottom are embossed to facilitate mounting on uneven wall surfaces.

Metal Nameplates: Switch catalog number, amperes voltage and horsepower ratings are permanently imprinted.

CLASS 73

SAFETY SWITCHES

(Reprinted through the courtesy of Furnas Electric Company, Batavia, Illinois.)

HEAVY DUTY

NEMA 3R Enclosures Features

- **Raintight Hubs:** The top of NEMA 3R enclosures have provisions for interchangeable hubs, ¾" through 3". A cover plate is included for use when hubs are not used.
- **Drip Shield:** NEMA 3R enclosures have a drip shield at top to prevent entrance of water. It also serves to support the top-hinged door which lifts up out of the way for wiring and maintenance.
- **Cover Interlock Defeater:** A screw on the enclosure side permits the cover interlock to be defeated and the door opened when the switch blades are closed.
- **Hookstick Operation:** A hole is provided on the handle of NEMA 3R enclosures for hoopstick operation. To gain access to the hole, cut away the red sleeve.
- **Knockouts:** Ample knockouts are provided in enclosure sides and bottom below the load terminals.

NEMA 3R

NEMA 12 Enclosure Features — NEMA 12 Enclosures have no unused openings; all holes and overlaps are sealed to prevent entry of foreign matter. These enclosures do not have any knockouts.

- **Mounting Brackets:** enclosures have external mounting feet (2 each at top and bottom) welded to the back of the enclosure. This arrangement also provides an air space between the enclosure and mounting surface.
- **Door Brackets:** Screw down brackets at top and bottom of enclosures seal the door securely to the enclosure box.
- **Door Latch:** Provided on all enclosures, this latch must be engaged before the switch blades can be closed.
- **Cover Interlock Defeater:** A screw on the side of enclosures permits the cover interlock to be defeated and the door opened when the switch blades are closed.
- **Hookstick Operation:** A hole is provided on the handle of enclosures for hookstick operation. To gain access to the hole, cut away the red sleeve.

NEMA 12

Answer the following questions:

1. What is a circuit breaker?

2. What is a fuse?

3. What is the difference between a circuit breaker and a fuse?

4. In what ampacity are fuses available?

5. What is the grouping of ampacity as to physical size of fuses?

1. Make the following connections in a fusible load center:

   A. 110v - 1Ø - 60

   B. 230v - 1Ø - 60

1. How are breakers installed in an electrical breaker panel?

2. If a breaker panel has no spare spaces, how can an electrician install additional circuits without adding additional panels?

3. What is the difference between a light duty breaker and a commercial breaker in the manner in which they are attached to the main lugs?

4. What is a main breaker?

5. What ampacity sizes are breakers available in?

1. Install a 1 pole, 2 pole, and 3 pole circuit breaker in a breaker panel.

1. Troubleshoot the following breakers or panels.

   A. Breaker panel

   B. 1 Pole Breaker

   C. 2 Pole Breaker

   D. Fusible Load Center

MAJOR BLOCK Electricity **NAME** _____

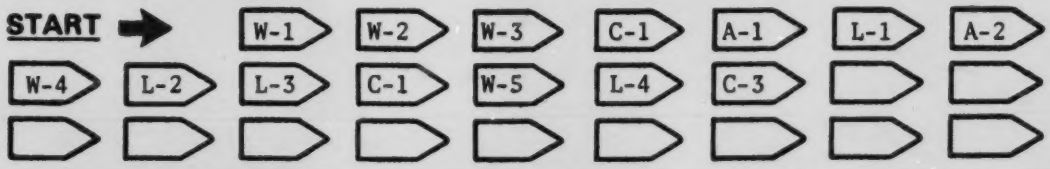
TASK Electric Motors

UNIT Servicing Shaded Pole Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-11

OBJECTIVE(S)

Install wire and operate a shaded pole motor.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-11a
W-2	Information Sheet EL-11a
W-3	Assignment Sheet EL-11a
W-4	Text Assignment EL-11b
W-5	Information Sheet EL-11b
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-11a
A-2	Slide Set EL-11b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-11a
L-2	Job Sheet EL-11b
L-3	Job Sheet EL-11c
L-4	Job Sheet EL-11d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Electric motors are manufactured in many different types and sizes depending upon their running and starting characteristics. In the heating and air conditioning industry there are many different applications that electric motors are used for such as fan motors and compressors. The starting characteristics of an electric motor is the most important factor to be considered. The torque of an electric motor is the strength that a motor produces while starting or running. Different types of motors usually vary the starting torque.

The application of an electric motor will dictate which type of motor is needed for a specific task. A small propeller type fan would only require a low starting torque. Some large fans require a motor with a medium starting torque, and a compressor on a refrigeration system that does not equalize on off cycle will require a high starting torque motor. There are basically 5 different types of motors used in the industry: shaded pole, split phase, permanent split capacitor motor, capacitor-start motor, capacitor-start, capacitor-run, and thru phase. The shaded pole motor has the lowest starting torque while the three-phase motor has the highest starting torque.

As an additional reading assignment concerning shaded pole motors and their comparison to other types of motors, the student is referred to an additional reading assignment: Electric Motors: selection, protection, and drives published by the American Association for Vocational Instructional Materials, 120 Ag Engineering Center, The University of Georgia, Athens, GA 30602. Page 15 in the 1972 edition and page 20 in the 1978 edition. Note: This reading assignment will not be reflected in the textbook list for the curriculum materials.

1. What is torque?

2. List the 5 general types of motors that are commonly used in the industry.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

3. What is the starting torque of a shaded pole motor?

4. List the 5 motors from question 2 in their order of starting torque.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

5. Why are different motors used for different applications?

The instructor will assign eight motors to identify according to type (SP-Shaded Pole, PSC-Permanent Split Capacitor, CS-Capacitor Start, CSR-Capacitor Start-Capacitor Run).

Motor #1 _____

Motor #2 _____

Motor #3 _____

Motor #4 _____

Motor #5 _____

Motor #6 _____

Motor #7 _____

Motor #8 _____

The instructor will assign a shaded pole motor for disassembly. Refer to the preceeding audio visual, reading assignments and information sheets if additional preparation is needed.

1. Dissassemble shaded pole motor.
2. Identify parts.
3. Reassemble shaded pole motor.

NOTE:

1. Make certain to mark the end bells and frame.
2. Do not damage any of the motor components in the operation.

The instructor will assign motors for this activity. Identify each motor by serial number.

Serial #

1. Operate a 110v single speed shaded pole motor. _____

2. Operate a 110v two spaced shaded pole motor on both speeds. _____

3. Operate a 230v two speed shaded pole motor on both speeds. _____

4. Reverse the motor used in Number 3.

   a. To reverse a split phase, the stator must be removed and and then reversed.

5. Install a shaded pole motor on a piece of equipment in the shop. The equipment should be identified by name and serial number.

   a. Type of equipment _____
   b. Serial number _____

Procedure for Troubleshooting a Shaded Pole Motor

1. When troubleshooting a shaded-pole motor, there are only two areas where problems can exist. The windings of a shaded-pole motor can be faulty or the bearing can be faulty.

2. The windings of a shaded pole motor can be checked with an ohmmeter. The windings can be open, shorted, grounded, or good. All speeds of the motor must be checked. When making a reading of a motor, it must be taken between the windings.

    a. If a motor has two wires touching within the frame, it is shorted. The ohmmeter reading in this case would be "0".

    b. If the windings of a motor are burned or broken, the motor is open. The ohmmeter reading in this case would be infinite.

    c. If the windings of a motor are exposed and touching the frame, the motor is grounded. The ohmmeter reading would measure between the frame and winding.

    d. If the motor is good, a measurable resistance will register between the windings.

3. The bearing of an electric motor can be checked by feeling the motion of the rotor when rotating the motor. Often when bad bearings exist, the motor is completely locked down. If the bearings are tight lubrication of the motor may correct the problem.

1. Troubleshoot three split phase motors in the shop. (Be specific as to fault of motor.)

Condition (Good, Faulty Windings, Bearings, Open Shorted, Grounded)

Motor #1 _____

_____

_____

Motor #2 _____

_____

_____

Motor #3 _____

_____

_____

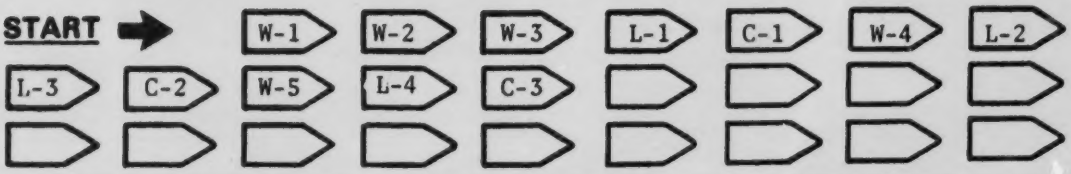
MAJOR BLOCK Electricity **NAME** _____

TASK Electric Motors

UNIT Wiring Split Phase Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-12

OBJECTIVE(S) Install and operate a 230 volt split phase motor.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-12a
W-2 Information Sheet EL-12a
W-3 Assignment Sheet EL-12a
W-4 Information Sheet EL-12b
W-5 Text Assignment EL-12b
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-12a
L-2 Job Sheet EL-12b
L-3 Job Sheet EL-12c
L-4 Job Sheet EL-12d
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Winding Layout of Split Phase Motor

The winding layout of split phase motors depends upon the voltage of the motor. The split phase motor is available to operate on 110 volts, 230 volts, and 115 volt/230 volts. Most split phase motors are made for single voltage operation.

Winding layouts of split phase single voltage motors are fairly simple. A diagram of the single voltage split phase motors is shown below.

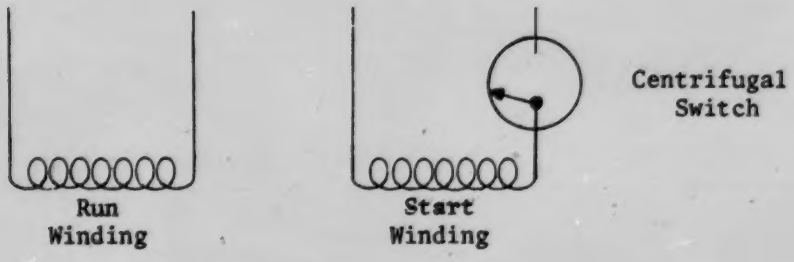


FIGURE A

The single run voltage motors have one run winding and one start winding with a centrifugal to drop it out. To hook up this type motor, connect each winding to the specified voltage. The centrifugal switch must be in series with the start winding. If overloads are used they would also have to be in series with the windings.

The dual voltage split phase motor has a different winding layout because it is used on 115/230 volts. The diagram below is of a dual voltage motor.

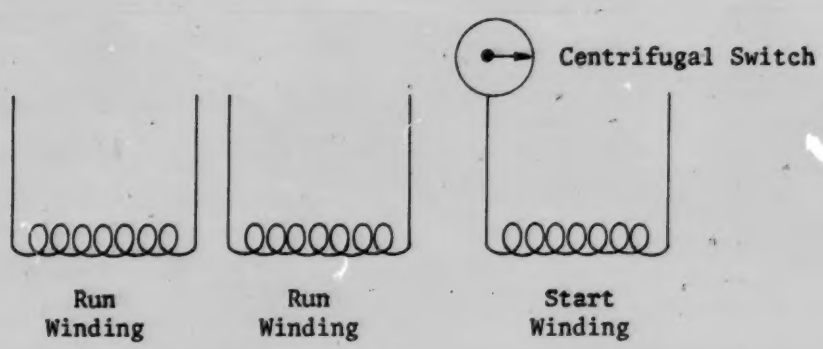


FIGURE B

The dual voltage motor when operated on 110 volts would be wired as below (Figure C).

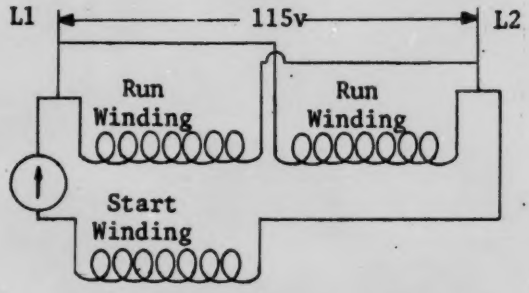


FIGURE C

Notice that all the winding are in parallel with 110 volts when installed on 230 volts. When installed on 230 volts, it would be wired as Figure D.

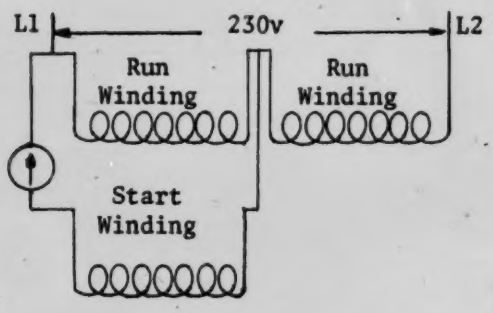


FIGURE D

Notice that the run windings are in series and the start winding is connected between the run windings in order to allow 115 volts to the start winding.

1. Explain the operation of a split phase motor.

2. Connect the following diagram of a dual voltage to 110 volts and 230 volts.

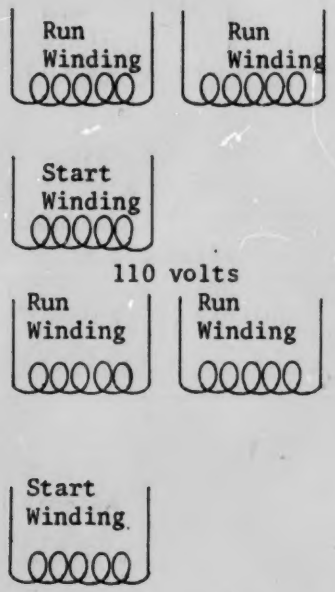


FIGURE E

3. Give 3 examples of the use of a split phase motor in the industry.

1. Locate windings in a 110v split phase motor.

2. Locate winding in a 230v split phase motor.

3. Briefly explain the differences between the 110v and 230v split phase motor.

Wiring a Split Phase Motor

When wiring a split phase motor, always use the following rules:

1. If possible, use wiring diagram on the motor.
2. If the diagram is missing, use one of the common diagrams on the next page.
3. If diagram is missing and one of the common diagrams is not current, you must ohm out the motor to determine the windings and then make the correct connections.

1. Wire, operate and reverse a 115v split phase motor without a diagram.
2. Wire, operate and reverse 230v split phase motor.
3. Wire, operate and reverse a dual voltage split phase motor.
4. Install split phase motor on equipment in shop.

Troubleshoot 3 split phase motors.

	Serial Number	Problem	Recommended Action
Motor #1	_____	_____	_____
Motor #2	_____	_____	_____
Motor #3	_____	_____	_____

1. Wire and operate a split phase hermetic motor with current relay.

2. Wire and operate a split phase hermetic motor with hot wire relay.

3. Explain the basic characteristic differences in these motors.

_____

_____

_____

_____

MAJOR BLOCK Electricity **NAME** _____

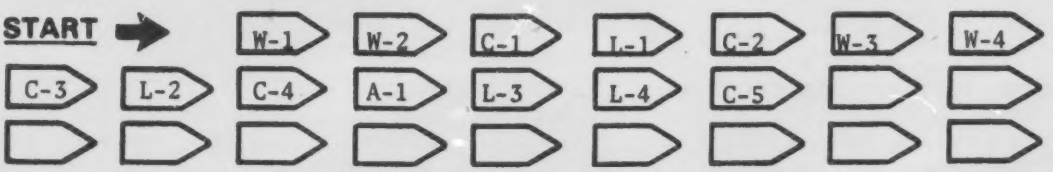
TASK Electric Motors

UNIT Checking Capacitors **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-13

OBJECTIVE(S)

Diagnose the condition and identify replacement capacitors on electric motors.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-13a
W-2	Assignment Sheet EL-13a
W-3	Information Sheet EL-13a
W-4	Assignment Sheet EL-13b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-13a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-13a
L-2	Job Sheet EL-13b
L-3	Job Sheet EL-13c
L-4	Job Sheet EL-13d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

A. Answer the following questions:

1. A capacitor is a device that,

   a. stores electrons.

   b. controls the capacity of a motor.

   c. creates a 3rd phase.

   d. increases the voltage available to a motor.

2. The symbol for a capacitor is:

   a.

   b.

   c.

   d.

3. An electrolytic capacitor,

   a. increases the running efficiency of a motor.

   b. increases the starting torque of a motor.

   c. can be purchased from 3 UF to 40 UR.

   d. is oil filled.

4. A running capacitor,

   a. increases the starting torque.

   b. increases the running efficiency of a motor.

   c. is oil filled.

   d. is all of the above

5. A starting capacitor stays in the motor circuit,

   a. only a short period of time.

   b. continuously.

   c. only when motor is (operating) on low voltage.

   d. only when motor drops below rated rpm.

6. A running capacitor stays in the motor circuit,

   a. only a short period of time.

   b. continuously.

   c. only when needed for torque assistance.

   d. only when the motor is operating on low voltage.

7. The running capacitor is oil filled to prevent,

   a. overheating.

   b. motor overloading.

   c. high current draw.

   d. all of the above conditions.

8. The difference between a running and starting capacitor is,

   a. their size (uF).

   b. their purpose in a motor circuit.

   c. length they stay in the motor circuit.

   d. all of the above.

1. Identify ten different capacitors as to running or starting, voltage, and micro-farad (uF) rating:

No.	Type Capacitor	Voltage	Micro-Farad Rating (uF)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Capacitor Rules

1. The voltage of capacitor used for replacement must be equal to, or greater than, the capacitor being replaced.

2. The strength of the starting capacitor replacement must be at least equal to but not greater than 20% of the capacitor being replaced.

3. The strength of the running capacitor replacement may vary plus 10% or minus 10% of the capacitor being replaced.

4. If capacitors are installed in parallel, the sum of the capacitors is the total capacitance.

5. The total capacitance of capacitors in series may be found by the following formula:

$$C = \frac{C_1 C_2}{C_1 C_2}$$

Answer the following questions:

1. The capacitance of a 125 UF and 150 UF starting capacitor connected in series is,

   a. 58 UF.

   b. 62 UF.

   c. 68 UF.

   d. 72 UF.

2. The capacitance of a 35 UF and 15 UF running capacitor connected in parallel is,

   a. 8.5 UF.

   b. 16.5 UF.

   c. 20 UF.

   d. 50 UF.

3. The voltage of a capacitor used for replacement must be _____ the capacitor being replaced.

   a. less than

   b. exactly the same as

   c. greater than

   d. 25% higher than

4. The strength of the starting capacitor replacement must be at least equal to but not greater than _____ of the capacitor being replaced.

   a. 5%

   b. 10%

   c. 15%

   d. 20%

5. The strength of the running capacitor replacement may vary plus or minus _____ of the capacitor being replaced.

   a. 5%

   b. 10%

   c. 15%

   d. 20%

6. If a capacitor produces 20 amps on 230 volts, what is its uF rating?

   a. 200 uF

   b. 230 uF

   c. 245 uF

   d. 260 uF

7. Replace a 210 uF 230v starting with which of the following selection?

   a. 230 uF/110v

   b. 230 uF/330v

   c. 230 uF/160v

   d. 210 uF/110v

8. Replace a 50 uF 370v running capacitor with which of or combination of the following capacitors:

   a. 50 uF/330v

   b. 45 uF/440v

   c. 40 uF/370v

   d. 60 uF/370v

9. Replace a 330 uF 250v starting capacitor with which of or combination of the following capacitors:

   a. 150 uF/330v

   b. 200 uF/250v

   c. 370 uf/110v

   d. 330 uf/221v

10. Replace a 35 uF, 330v running capacitor with one or a combination of which of the following capacitors:

   a. 15 uF/370v

   b. 20 uF/370v

   c. 40 uF/440v

   d. 30 uF/440v

11. Replace a 20 uF 350v running capacitor with one or a combination of the following capacitors:

   a. 40 uF/290v

   b. 40 uF/290v

   c. 28 uF/330v

   d. 10 uF/330v

12. Replace a 108 uF 250v starting capacitor with one or a combination of the following:

   a. 25 uF/250 volt

   b. 60 uF/250 volt

   c. 80 uF/250 volt

   d. 100 uF/250 volt

The instructor will assign an assortment of capacitors. Determine which of those capacitors should replace those listed below.

	ORIGINAL	REPLACEMENT FROM ASSIGNED CAPACITORS
1.	330 ufd - 250v Start	_____
2.	40 ufd - 370v Run	_____
3.	15 ufd - 440v Run	_____
4.	110 ufd - 110v Start	_____
5.	284 ufd - 150v Start	_____
6.	30 ufd - 370v Run	_____
7.	35-5 ufd - 440v Run	_____
8.	88 ufd - 150v Start	_____
9.	6 ufd - 370v Run	_____
10.	290 ufd - 250v Start	_____

Job Sheet EL-13c

Check the assigned capacitors with an ohmmeter and at least two capacitor checkers.

NO.	TYPE CAPACITOR	CONDITION	CAPACITOR TESTER #1	CAP TESTER #2
#1				
#2				
#3				
#4				
#5				
#6				
#7				
#8				
#9				
#10				
#11				
#12				
#13				
#14				
#15				
#16				
#17				
#18				
#19				
#20				

Determine the rating of 5 capacitors whose markings are not legible.

a. Use the following circuit to obtain the readings needed to determine the rating of the capacitors

b. Use the following formula to calculate the rating of the capacitors:

$$\text{Micro-farads (uF)} = \frac{2650 \times \text{amperes}}{\text{volt}}$$

c. Do not keep the capacitor in the circuit over 5 seconds.

d. Record the information in the following chart:

CAP	VOLTAGE	AMPERES	CAPACITOR RATING

MAJOR BLOCK Electricity **NAME** _____

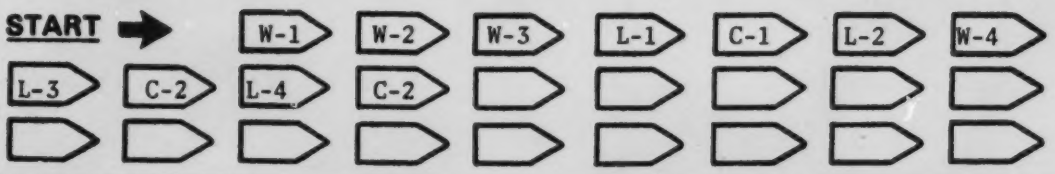
TASK Electric Motors

UNIT Hooking up and Troubleshooting a PSC Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-14

OBJECTIVE(S)

Wire, install and operate (PSC) permanent split capacitor motor.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-14a
W-2	Information Sheet EL-14a
W-3	Assignment Sheet EL-14a
W-4	Information Sheet EL-14b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-14a
L-2	Job Sheet EL-14b
L-3	Job Sheet EL-14c
L-4	Job Sheet EL-14d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

One of the most popular motors used in the industry is the permanent split capacitor motor (PSC). It is a low starting torque motor and is used primarily on fans and compressors where the refrigeration equalizes on the off cycle. There are various types of PSC motors used in the industry. Some of the common types are single voltage one speed, single voltage one speed reversible, single voltage two speed and single voltage three speed. The single voltage one speed PSC motor is used on condenser fan motors and compressors while the two and three speed PSC are used for evaporator fan motors or furnace fan motors.

A schematic diagram of a single voltage one speed is shown in Figure A.

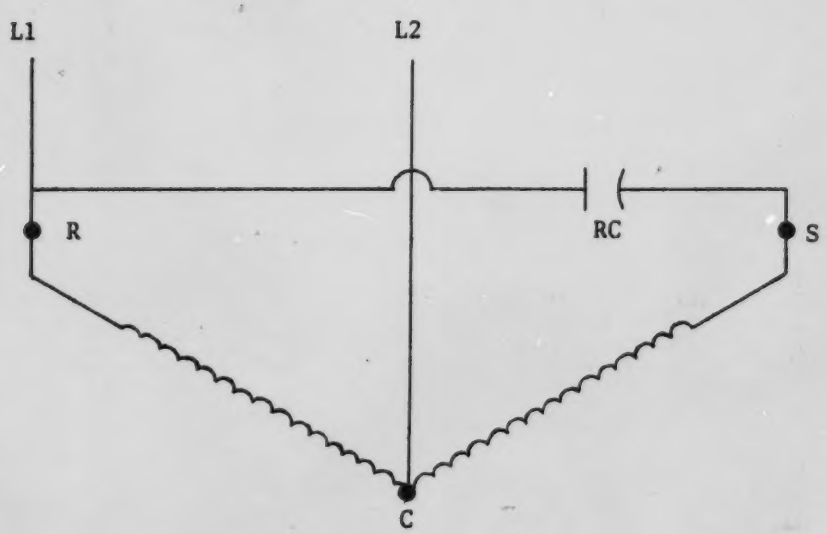


FIGURE A

An oil capacitor (running) is used with most PSC motors. The running capacitor should always be connected between the power side of the run winding and the start winding. Several manufacturers bring separate leads out of the motor for the connection of the capacitor. These leads are usually brown.

The single speed PSC motor is used for motors in compressors. The diagram is the same as above. The only difference is that in a compressor, the total motor is enclosed within a steel shell.

A multispeed PSC motor does not require a change in the number of poles to change but merely places an auxiliary set of windings in series with the main to decrease the magnetic field causing a slow down in speed. The following figures show a 2 speed PSC motor schematically.

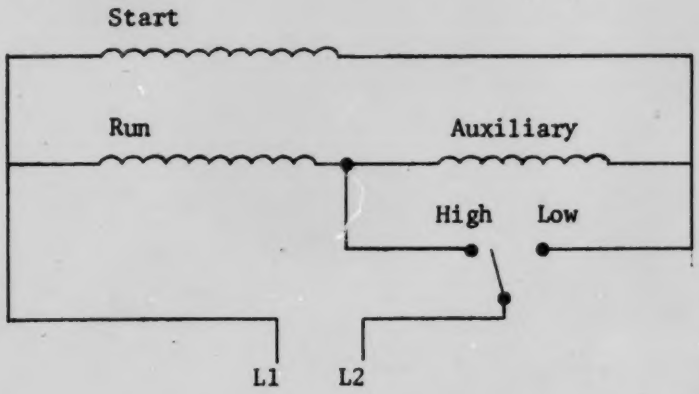


FIGURE B

The following two charts will supply a guide to install a multispeed PSC motor.

Answer the following questions:

1. What is the purpose of a running capacitor when used with a PSC motor?

2. Draw a wiring diagram of a single speed PSC motor.

3. List at least 5 common uses of the PSC motor.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

4. What is the common color coding of multiple speed PSC motors?

5. Explain how to ohm out a PSC multispeed motor.

The instructor will assign a permanent split capacitor (PSC) multispeed motor for disassembly. If motor disassembly needs to be reviewed, refer to Slide Set EL-12b.

1. Disassemble PSC multispeed motor.

2. Examine, identify, and label the parts.

3. Reassemble motor.

4. Wire and operate the motor.

1. Wire and operate the following PSC motors.

	Serial Numbers
a. 110 volts single speed	_____
b. 110 volt two speed	_____
c. 230 volt two speed	_____
d. 230 volt four speed	_____
e. 250 volt hermetic compressor	_____

NOTE: It is difficult to reverse a PSC motor unless it is equipped with reversing terminals.

Procedure for Troubleshooting a PSC Motor

The procedure for troubleshooting a PSC motor is the same as other motors already discussed in earlier units. When troubleshooting a PSC motor, the capacitor, motor windings, and bearings must be checked.

A. The windings may be open, shorted, grounded or good. All windings must be checked.

B. Check the bearings.

C. Check the capacitor.

The instructor will assign three PSC motors to troubleshoot. Include the necessary information below.

	Serial Number	Type of Motor	Problem
Motor #1	_____	_____	_____
Motor #2	_____	_____	_____
Motor #3	_____	_____	_____

The instructor will assign two PSC hermetic motors to troubleshoot. Include the following information for each.

	Serial Number	Problem	Recommendation
Motor #1	_____	_____	_____
Motor #2	_____	_____	_____

MAJOR BLOCK Electricity **NAME** _____

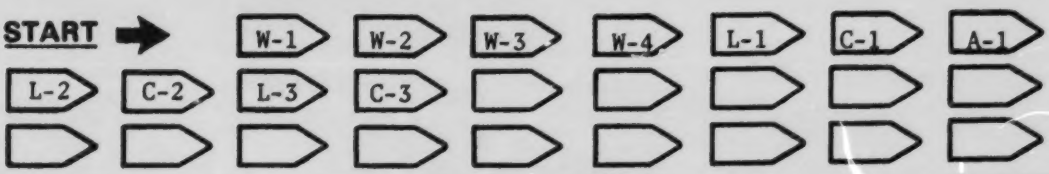
TASK Electric Motors

UNIT Hooking Up & Troubleshooting CS Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-15

OBJECTIVE(S)

Wire, troubleshoot and install open type capacitor start motors.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-15a
W-2	Information Sheet EL-15a
W-3	Text Assignment EL-15b
W-4	Assignment Sheet EL-15a
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-15a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-15a
L-2	Job Sheet EL-15b
L-3	Job Sheet EL-15c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

The capacitor start (CS) motor is used in many parts of the industry. The CS motor is used on some fans that require a high starting torque such as many small compressors (1/4 HP to 3/4 HP). The CS motor is manufactured in an open type motor and in hermetic compressors from 1/4 HP to 3/4 HP.

The CS motor is much like the split phase motor with the exception of not having a starting capacitor. The open type CS motor has a starting capacitor that is removed from the circuit by a centrifugal switch when the motor reaches 75% of full speed. The CS motor has a high starting torque.

The CS hermetic motor is used almost exclusively in hermetic compressors. When a motor is put in a housing, enclosed with freon and oil, it is impractical to use a centrifugal switch. If a centrifugal switch is not used some type of relay must be used to drop out the starting winding and the starting capacitor.

When a relay is used to drop the starting components out of a circuit, it will mechanically remove these components by using a relay controlled by a thermal element, a magnetic coil, or a voltage coil. The thermal element and magnetic coil will be discussed in this section. The voltage coil will be discussed in the next lesson. The thermal element starting relay would drop the starting winding and starting capacitor out of the circuit by detecting the heat produced by the motor on start up. A hot wire relay (starting relay w/thermal element) and wiring diagram of the relay are shown in the text reading assignment. The current type relay will drop the starting components out of the circuit by sensing the current draw on startup of a CS motor. Two current type relays and a diagram of the relays are again shown in the text reading assignment.

Because all hermetic motors are totally enclosed, it is imperative that a mechanic be able to determine the common, start, and run terminal of a hermetic motor. The common terminal of a hermetic motor is where the run winding and start winding connect in the diagram shown below.

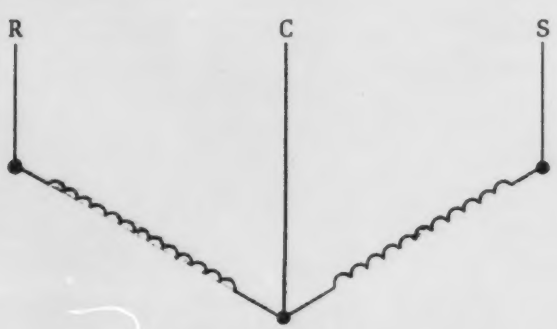
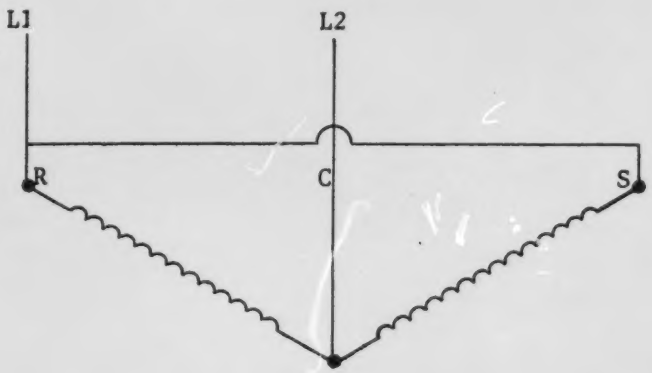


FIGURE A

The run terminal is where the run winding connects to the common and is externally connected to the outside shell terminal. The start terminal is where the start winding connects to the common and also connects externally. The diagram shows where power would be connected to the motor without any starting apparatus. The start would be connected through a relay and a starting capacitor on a CS motor. A PSC motor would install a running capacitor in series with start winding. A split phase motor would have a starting relay in series with the start winding. The text assignment gives an explanation of how to determine the common, start and run terminal of a hermetic motor.



Answer the following questions:

1. Draw the schematic of a CS hermetic motor.

2. What is the difference between a hot wire relay and current type relay?

3. What is the difference between a split phase motor and a capacitor start motor?

4. What is a hermetic motor?

5. What is a hot wire relay?

The instructor will assign you an open type capacitor-start motor for disassembly. Use the procedures described in previous units.

1. Disassemble an open type capacitor-start motor.

2. Examine the parts of an open type capacitor start motor and label according to specific component.

3. Reassemble the above capacitor start motor.

Wire and operate the following types of CS motors (also take current reading of motor).

	Serial Number	Amps
1. 110v CS motor	_____	_____
2. 230v CS motor	_____	_____
3. Dual voltage CS motor	_____	_____
a. 110v	_____	_____
b. 230v	_____	_____
4. 110v hermetic CS	_____	_____

Troubleshoot the following CS motor; denoting the problem with the motor.

a. Open Type CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

b. Open Type CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

c. Hermetic CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

d. Hermetic CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

MAJOR BLOCK Electricity **NAME** _____

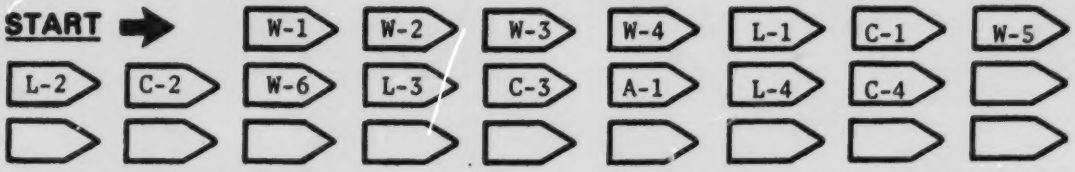
TASK Electric Motors

UNIT Hooking up and Troubleshooting a CSR Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-16

OBJECTIVE(S)

Troubleshoot and hook up a CSR motor and starting relay.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-16a
W-2	Text Assignment EL-16b
W-3	Assignment Sheet EL-16a
W-4	Information Sheet EL-16a
W-5	Information Sheet EL-16b
W-6	Text Assignment EL-16c
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-16a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-16a
L-2	Job Sheet EL-16b
L-3	Job Sheet EL-16c
L-4	Job Sheet EL-16d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Determine what type of relay is described (current, potential, hot wire) in the definitions below.

Draw a schematic of a CSR motor below each definition to include the described relay.

A. Uses voltage to energize its coil and cuts the starting components out of the circuit once the motor is running.

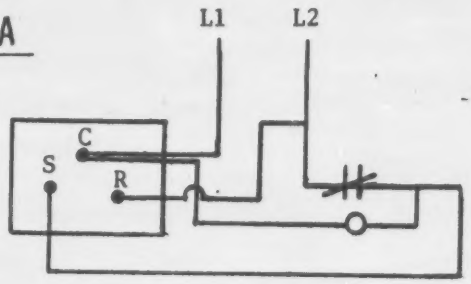
B. Uses heat to open and close the starting circuit.

C. Uses current flow to energize the starting circuit and then cuts out the circuit when the current drops.

In the previous package, capacitor start (CS) motors were described. Because of the similar characteristics between CS and capacitor start-capacitor run (CSR) motors, a short review of the CS motor using a potential relay is included here.

The CS motor has one start capacitor in series with a set of contacts and the start winding. This capacitor is used to assist the motor in starting due to a difference in the timing the current gets to the start winding and the run winding. The CS motor has a high torque. Small capacitor start motors use a current type relay or a hot wire relay to drop the start winding and start capacitor out of the circuit. On larger CS motors, the potential relay is used to drop the starting components out of the circuit. The following diagram shows the wiring of a CS motor with a potential relay. (Figure A)

FIGURE A



If you have any problems determining the common, start, or run terminal of a compressor, see paragraph 6.11 in Text #3.

The CSR motor is available for commercial refrigeration and air conditioning applications which use some type of metering device that does not equalize pressures at the compressor off cycle. The CSR motor differs from the CS motor in that two capacitors are used in the circuit. This is one of the most common motors used in the industry today. This motor has a high starting torque and excellent running efficiency. This motor has two capacitors, a start capacitor and a run capacitor in parallel. The two capacitors in parallel are in series with the start winding. Once the motor has come to speed, the start capacitor is removed from the circuit by the potential relay. The run capacitor and the start winding remain in the circuit after the motor has come up to speed. Thus while the motor is operating, there will be two windings with currents of different timing resulting in a very efficient running single phase motor. Before power is applied, the contacts of the potential relay are closed (they are normally closed). When power is applied to the start winding, there is a very small

back EMF or back voltage. As the motor comes up to speed, a high voltage is induced in the start winding. The coil of the potential relay is in parallel with the start winding and also has this voltage across it. It will then open the relay contacts and remove the start capacitor from the circuit. The following schematic diagram shows a hermetic motor, start capacitor, run capacitor and a potential relay. (Figure B)

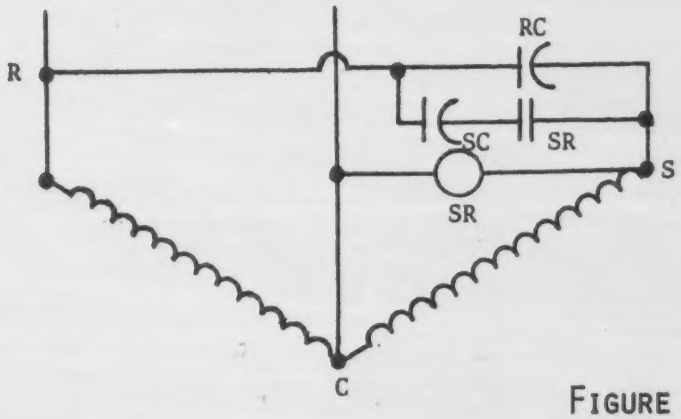


FIGURE B

The following diagram is a sectional diagram of a CSR motor hookup. (Figure C)

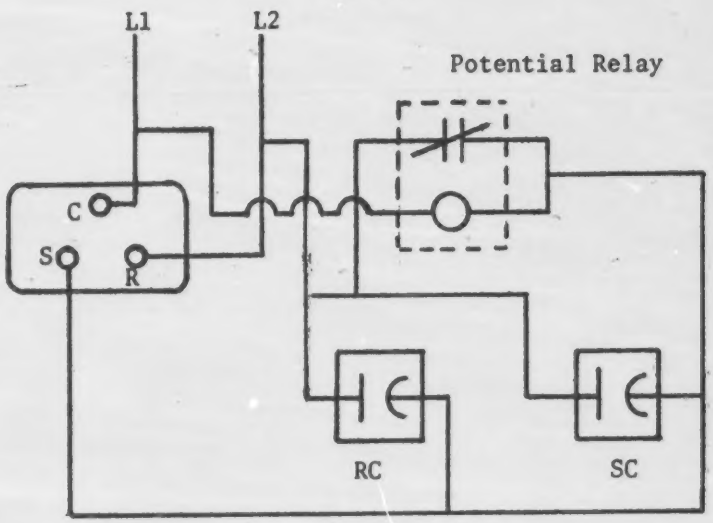


FIGURE C

Have the instructor assign the necessary tools and equipment to perform the following jobs.

A. Wire and operate a CS motor with a potential relay.

B. Add a running capacitor to the CS motor to make a CSR motor.

C. Wire and operate the CSR motor.

Hard Start Kits for Air Conditioners

When a permanent split capacitor motor (PSC) is used on an air conditioner, the refrigeration system must equalize on the off cycle in order for the compressor to start again. If the refrigeration system does not equalize, the compressor would require a high starting torque motor. A PSC compressor motor is usually designed so that by adding a starting capacitor and a potential relay, the motor becomes a CSR motor.

A hard start kit is nothing more than a starting capacitor and potential relay. Manufacturers sell hard start kits as a package to go on their equipment. The same components can be purchased at local wholesalers, but care should be taken to obtain the correct components.

There are several reasons why a hard start kit should be installed on an air conditioner. One reason is that the refrigeration system will not equalize before the unit comes back on. Sometimes a compressor can be slightly tight and a hard start kit will assist the unit in starting. Low voltage at times will hinder compressors from starting properly and a hard start kit will usually remedy this problem. There are other reasons why hard start kits are installed on equipment but these are the most common reasons.

The following diagram will show the proper wiring (in dashed lines) used to install a hard start kit on a PSC motor. (Figure D)

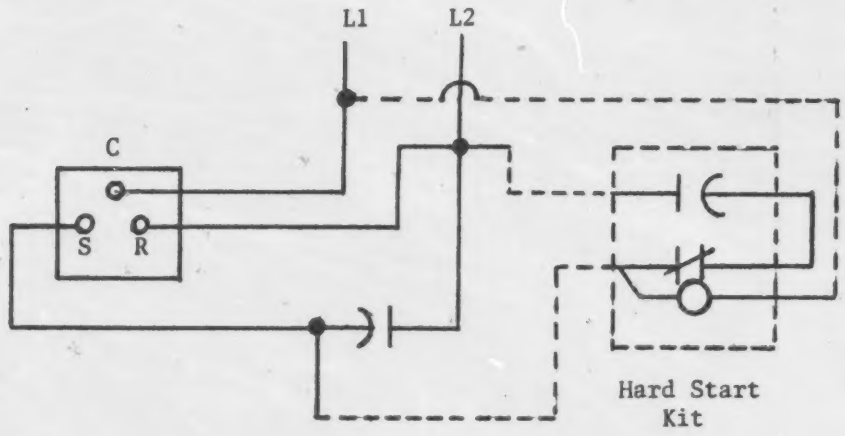


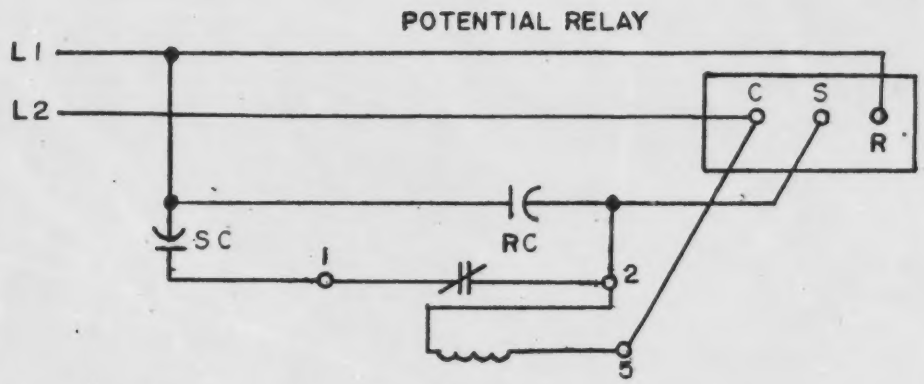
FIGURE D

Obtain the necessary tools and equipment to install a hard start kit on a residential air conditioner containing a PSC motor. The instructor will assign the AC unit. Record the serial number here.

S/N_____

Obtain the necessary tools and equipment to check the potential relays on the units assigned by the instructor. Be sure to record the unit serial number. Use the wiring diagram below as a general guide.

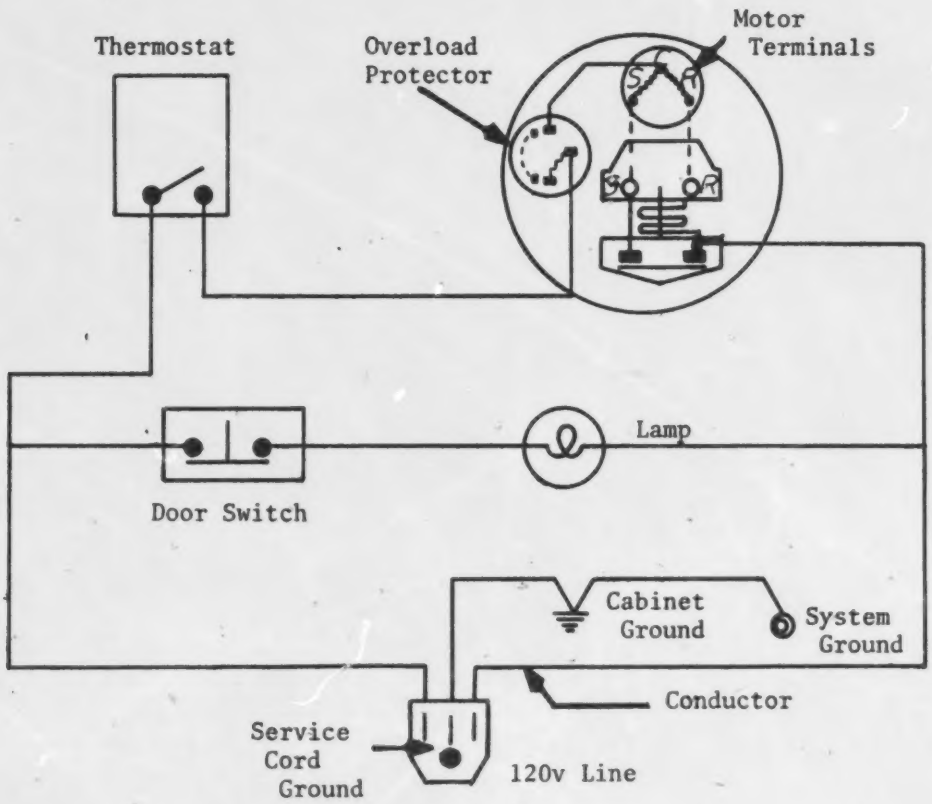
		Fault, If Any
Unit S/N _____	Relay #1	_____
Unit S/N _____	Relay #2	_____
Unit S/N _____	Relay #3	_____



Schematic diagram of a potential relay.

Obtain the necessary tools and equipment and troubleshoot the CSR motors found on the assigned Air Conditioning units. Be sure to record the Air Conditioning unit serial number. Use the diagram below as a general aid.

		Fault, If Any
A/C Unit S/N _____	CSR #1	_____
A/C Unit S/N _____	CSR #2	_____
A/C Unit S/N _____	CSR #3	_____



MAJOR BLOCK Electricity **NAME** _____

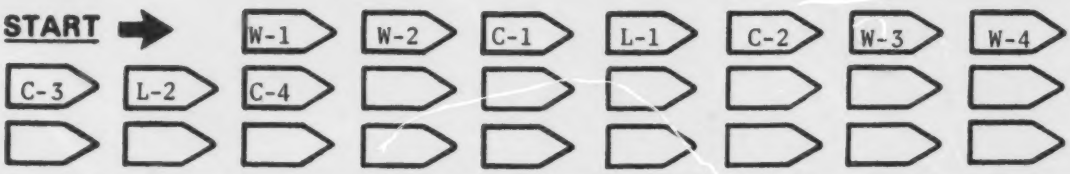
TASK Electric Motors

UNIT Hooking up a three Phase Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-17

OBJECTIVE(S)

Properly hook up and install three phase motors



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-17a
W-2	Assignment Sheet EL-17a
W-3	Text Assignment EL-17b
W-4	Assignment Sheet EL-17b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-17a
L-2	Job Sheet EL-17b
L-3	
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Refer to the previous Text Assignment and answer the following questions.

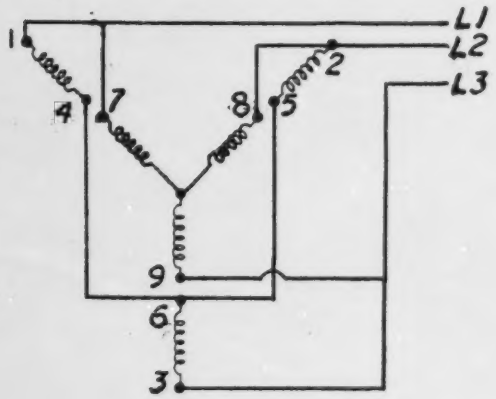
1. What is the advantage of using a 3 phase motor?

2. How does a 3 phase motor operate?

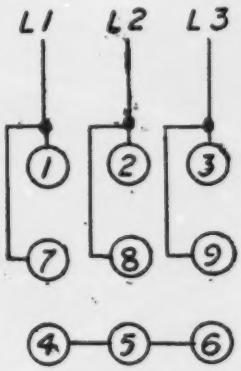
3. What is the starting torque of a 3 phase motor in comparision to a split phase or a CSR motor?

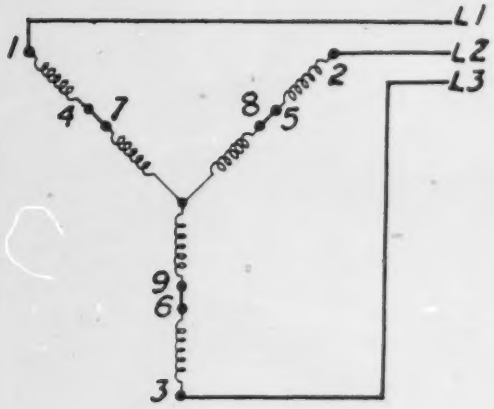
4. Explain the motor winding makeup of a 3 phase motor. Give an explanation of how it is wired on low and high voltage.

Using the following diagram and the assigned motors to wire, operate, measure amperage, and reverse direction of three 3-phase motors. (Reversing is accomplished by switching any two of the line voltage leads.)

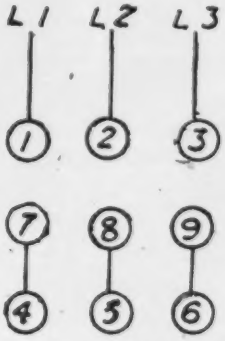


208/220





440 VOLTS



Motor S/N	Voltage	AMPS on low volts	AMPS on high volts
	Single		
	Dual		
	Dual		

Caution: Use extreme care in handling the high voltages.

Refer to the previous Text Assignment and answer the following questions.

1. How do you troubleshoot a 3 phase motor?

2. What two problems could be encountered with a 3 phase motor?

3. How many sets of windings does a single voltage 3 phase motor have?

4. What resistance reading would indicate a good 3 phase motor?

Using an ohmmeter and a wiring diagram, troubleshoot the windings of the following motors. Record the findings in the chart below and indicate faults, if any, that were identified.

Ohms Resistance in Windings

	Motor S/N	#1	#2	#3	#4	#5	#6
1.							
2.							
3.							
4.							
5.							

Motor No. Faults

1. _____

_____

2. _____

_____

3. _____

_____

4. _____

_____

5. _____

_____

MAJOR BLOCK Electricity **NAME** _____

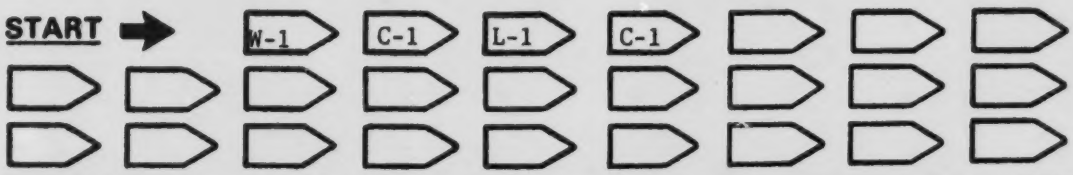
TASK Electric Motors

UNIT Testing Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-18

OBJECTIVE(S)

Determine motor failure causes of shaded pole, split phase, PSC, CS, CSR, and three phase motors.



WRITTEN ASSIGNMENT(S)

W-1 Assignment Sheet EL-18a
W-2 _____
W-3 _____
W-4 _____
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-18a
L-2 _____
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 _____
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

The preceeding electrical learning packages (EL-12 through EL-18) have dealt with servicing and replacement of the different types of motors used in heating, refrigeration, and air conditioning equipment.

Using the skills that have been developed in these electrical packages, locate each motor in the shop that is listed in Column A and record the serial number in Column B.

A	B
Shaded Pole	S/N _____
Split Phase	S/N _____
Permanent Split Capacitor (PSC)	S/N _____
Capacitor Start (CS)	S/N _____
Capacitor Start-Capacitor Run (CSR)	S/N _____
Three Phase	S/N _____

Select at least one of each type of motor listed on the previous Assignment Sheet and record the information requested on the chart. State the fault as bearing failure, winding open or shorted, starting component failure, etc. If the motor checks good, record the amp reading.

Motor S/N	Type Motor	Fault	Amp Draw

MAJOR BLOCK Electricity **NAME** _____

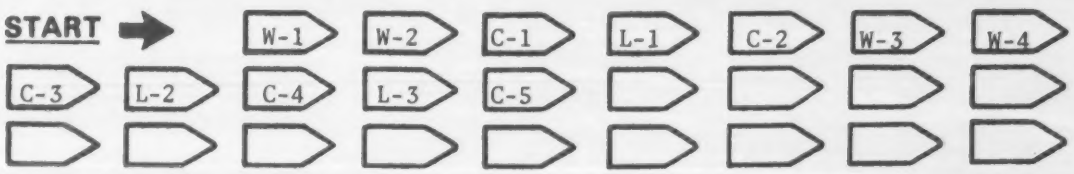
TASK Electric Motors

UNIT Maintenance of Electric Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-19

OBJECTIVE(S)

Perform maintenance on electric motors including changing and lubricating bearings, aligning belts and installing drive couplings.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-19a
W-2	Assignment Sheet EL-19a
W-3	Text Assignment EL-19b
W-4	Assignment Sheet EL-19b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-19a
L-2	Job Sheet EL-19b
L-3	Job Sheet EL-19c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	
C-7	
C-8	
C-9	

Answer the following questions by placing an X if the statement is True and an O if the statement is False in the space provided.

_____1. The two most common types of bearings used in electric motors are the ball bearing and sleeve bearing.

_____2. The ball bearing is more efficient than a sleeve bearing.

_____3. The sleeve bearing is the most economical bearing available.

_____4. A permanently lubricated ball bearing is lubricated and sealed at the factory.

_____5. Some ball bearings are lubricated with oil.

_____6. Some ball bearings must be replaced instead of lubricated.

_____7. A hand packed ball bearing should be lubricated every two to five years.

_____8. Some ball bearings are lubricated through special grease fittings.

_____9. Ball bearings are used in most hermetic compressor motors.

____10. A sleeve bearing is lubricated with oil.

____11. A sleeve bearing that is lubricated by the yarn packed method should be lubricated yearly.

Select five motors in the shop and record their serial numbers in the chart below. Determine the type of bearing (ball or sleeve) and record. Show method of lubrication used.

Motor Serial Number	Method of Lubrication	Type of Bearings (Back) Left End	(Front) Right End

A. Answer the following questions by placing an X if the statement is True or an O if the statement is False in the space provided.

_____ 1. Direct drives are used for connecting the motor shaft to equipment that runs at the same speed.

_____ 2. A V-belt is the most popular belt to connect a motor to a piece of equipment.

_____ 3. V-Belts are available in three different widths.

_____ 4. An adjustable pulley can be used to change the speed of the motor.

B. Answer the following questions:

5. How should a motor be aligned with a rotating device?

6. What is the correct tension on a V-Belt that connects a motor to a piece of equipment that requires rotation.

Complete the following:

1. Inspect two V-Belt applications and adjust belt tension.

	Belt Length
Motor S/N _____	_____
Motor S/N _____	_____

2. Inspect four direct drive motors and list coupling type.

	Type of Coupling
Motor S/N _____	_____
Motor S/N _____	_____
Motor S/N _____	_____
Motor S/N _____	_____

Perform the following tasks on the units assigned by the instructor.

1. Unit Serial No. _____

   (a) Change belts and adjust to correct tension.

4. Unit Serial No. _____

   (a) Correctly align V-belt application.

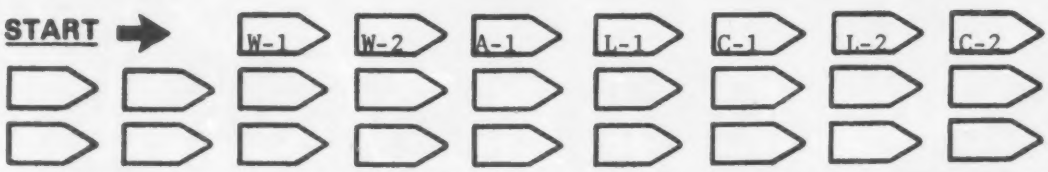
MAJOR BLOCK Electricity **NAME** _____

TASK Electrical Components

UNIT Installing and Testing a Transformer **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-20

OBJECTIVE(S) Troubleshoot and change out a transformer on a small residential air conditioner.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-20a
W-2 Information Sheet EL-20a
W-3 _____
W-4 _____
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-20a
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-20a
L-2 Job Sheet EL-20b
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 _____
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Special Purposes of Transformers

Transformers serve several special applications in the heating and air conditioning industry as well as the electrical industry. Transformers are used to increase or decrease the voltage that is applied to the primary side. The larger the load on a transformer the larger the physical size. Transformers used to supply the power to a control circuit of a small air conditioning unit are usually small and are generally rated in VA (volt amps) while transformers used to supply line voltage loads are rated in KVA.

The air conditioning industry has attempted to standardize the control voltage on large equipment to 110 volts. The only difference between a 230v/24v and a 230v/110v transformer is their physical size and the secondary voltage. Both transformers are installed in the same way.

The buck and boost transformer is used when equipment rated at 208 volts is used on 230 volts. This transformer will take a primary voltage of 208 voltage and raise the voltage to 230 volts. Figure A illustrates the schematic of a buck and boost transformer hooked into a circuit.

Most large commercial and industrial buildings will use transformers to redue the large voltage supplied by the power company to the desired voltage of the structure. For example many large buildings will be supplied 460 volts and the owners of the structure will purchase transformers to reduce the voltage to the desired voltage. It is more economical for companies to do this, because 460v equipment operates more efficiently than does the lower voltage.

A. The instructor will assign transformers to be checked. Record the transformer number in the space provided and as the checks are performed record the results in the appropriate columns.
NOTE: Be sure to apply load when making voltage check.

		Ohm Check		Volt Check		Condition
	Transformer ID No.	Primary	Secondary	Primary	Secondary	
1.						
2.						
3.						
4.						
5.						

B. The instructor will assign an air conditioning unit that may or may not have a faulty transformer.
1. Record the unit and transformer serial numbers in the space provided.
2. Remove the transformer and perform the voltage and ohm tests and record.
3. Record whether the transformer is satisfactory or unsatisfactory.
4. Show this information to the instructor.

Unit No. _____

Transformer No. _____

Condition _____

Readings

Ohms		Volts	
Pri.	Sec.	Pri.	Sec.

1. Install a buck and boost transformer on a small residential A/C in the shop and record the following:
   a. Serial number of air conditioner
   b. Serial number of transformer
   c. Line voltage
   d. Voltage supplied to equipment before illustation of buck and boost transformer.
   e. Voltage supplied to equipment after illustration of buck and boost transformer.

Unit S/N	Trans S/N	Line Voltage	Equip Voltage before install.	Equip Voltage after install.

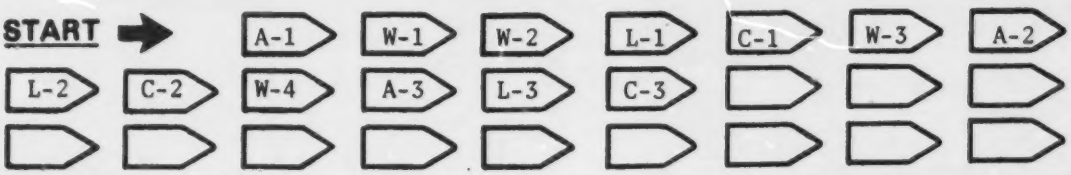
MAJOR BLOCK Electricity **NAME** _____

TASK Electrical Components

UNIT Installing and Testing Contacts and Relays **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-21

OBJECTIVE(S)



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-21a
W-2	Assignment Sheet EL-21a
W-3	Text Assignment EL-21b
W-4	Text Assignment EL-21c
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-21a
A-2	Slide Set EL-21b
A-3	Slide Set EL-21c
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-21a
L-2	Job Sheet EL-21b
L-3	Job Sheet EL-21c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

Answer the following questions:

1. What is the difference between a contactor and a relay?

2. What do the terms normally open and normally closed, refer to in respect to relays and contactors?

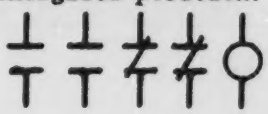
3. What are the 3 major parts of a contactor?

   1. _____

   2. _____

   3. _____

4. Change the following contacts from the de-energized position to the energized position.



5. What are the two types of armatures used in relays?

   1. _____

   2. _____

6. What are the contacts of a contactor made of? _____

   _____

7. Explain the two types of loads.

   1. _____

   2. _____

8. How does a contactor operate?

9. Draw a wiring diagram of relay controlling a motor.

10. Draw a wiring diagram of a contactor controlling a 3 phase motor.

The instructor will assign a contactor and a relay for part identification and disassembly.

1. Inspect sealed relay and identify parts.

2. Disassemble a contactor and identify the parts.

   A. List all of the parts of the contactor below. Label each part and ask the instructor to examine the results. Upon instructor approval, reassemble the contactor.

   B. List and label all parts of the relay. Upon the instructor's approval, reassemble the relay.

1. Draw a diagram, wire and operate a relay controlling a light with a single pole switch. (Relay has 110v coil)

2. Draw a diagram, wire, and operate a relay to control 110v fan motor with a single-pole switch. (Relay has a 24v coil).

3. Draw a diagram, wire, and operate a contactor to control a 230v compressor with a single pole switch. (Relay has 208v coil)

1. Troubleshoot 3 relays assigned by instructor.

	Fault
Relay #1	
Relay #2	
Relay #3	

2. Troubleshoot 2 relays in equipment circuits assigned by instructor and change if necessary.

	Fault
Relay #1	
Relay #2	

3. Troubleshoot 3 contactors assigned by instructor.

	Fault
Contactor #1	
Contactor #2	
Contactor #3	

4. Troubleshoot 2 contactors in equipment circuits assigned by instructor and change if necessary.

	Fault
Contactor #1	
Contactor #2	

MAJOR BLOCK Electricity **NAME** _____

TASK Electrical Components

UNIT Installing and Checking Thermostats **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-22

OBJECTIVE(S)

Install and check low voltage and line voltage thermostats.

START ➡ W-1 → A-1 → L-1 → C-1 → W-2 → W-3 → L-2 → C-2 → W-4 → W-5 → W-6 → L-3 → C-2 → W-7 → L-4 → C-3 → W-8 → L-5 → L-6 → C-4 → A-2 → L-7 → C-5

WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-22a
W-2	Information Sheet EL-22a
W-3	Assignment Sheet EL-22a
W-4	Text Assignment EL-22b
W-5	Information Sheet EL-22b
W-6	Assignment Sheet EL-22b
W-7	Assignment Sheet EL-22c
W-8	Text Assignment EL-22c

AUDIOVISUAL(S)

A-1	Slide Set EL-22a
A-2	Slide Set EL-22b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-22a
L-2	Job Sheet EL-22b
L-3	Job Sheet EL-22c
L-4	Job Sheet EL-22d
L-5	Job Sheet EL-22e
L-6	Job Sheet EL-22f
L-7	Job Sheet EL-22g
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	
C-7	
C-8	
C-9	

I. Identify and examine five low voltage thermostats and record the necessary information in the chart below.

Thermostat Number	Type of Element	Snap Action Method	Manufacturer	Range
#1				
#2				
#3				
#4				
#5				

II. Identify and examine five line voltage thermostats and record the necessary information in the chart below.

Thermostat Number	Type	Application	Range	Voltage	Controlling Element
#1					
#2					
#3					
#4					
#5					

Line Voltage Thermostat Applications

Line voltage thermostats are commonly used in many different control systems in the industry. Line voltage thermostats are used in control circuits with 110 volts or more. The following is a list of common applications of line voltage thermostats.

A. Refrigerators and freezers
B. Window air conditioners
C. Packaged air conditioners for wiring diagram
D. Control of loads in air conditioning systems
    1. Condenser fan motors
    2. Supplementary heaters

There are many other applications where line voltage thermostats are used. It should not be difficult to determine the function of line voltage thermostats from a wiring diagram.

Answer the following questions:

1. What is the difference between a line voltage and low voltage thermostat?

2. What is the advantage of using a low voltage thermostat?

3. What is a bi-metal converter?

4. What is the difference between a heating and cooling thermostat?

5. Where are line voltage thermostats used?

The instructor will assign units on which both low voltage and line voltage thermostats should be installed.

1. Install line voltage thermostat on an air cooled packaged unit.

   Unit Model # _____

   Type Thermostat_____

2. Install a line voltage thermostat on a commercial furnace.

   Unit Model # _____

   Type Thermostat _____

Low Voltage Thermostat Letter Designations

Low voltage thermostats have many functions such as controlling heating and cooling, fan, and many auxiliary functions. Below is a listing of the letters with their functions. Manufacturers do not use the same letter designations, so several manufacturer's letter designations are listed.

R - V	Power to thermostat from transformer
W1 - H1	First Stage Heat
W2 - H2	Second Stage Heat
X1 - C1	First Stage Cool
X2 - C2	Second Stage Cool
G - F	Fan
B	Supplementary Heat Function
O	Supplementary Cool Function

Manufacturers of equipment often use special thermostats that must be purchased from the manufacturer. Most gas furnaces with air conditioning use a common thermostat. However, many heat pumps use the specialized thermostats.

Answer the following questions:

1. Give three applications of a low voltage thermostat.

2. What do the following letters represent in a low voltage thermostat?

R _____	F _____
G _____	C _____
H _____	Y _____
W1_____	B _____
W2_____	O _____

3. Draw a diagram of a low voltage thermostat with fan function and heat-cool function.

1. Install a low voltage thermostat on a gas furnace.

   Furnace Model # _____

   Thermostat Type_____

   NOTE: See installation instructions.

2. Install a low voltage thermostat on a packaged air conditioner.

   Air Conditioner Model #_____

   Thermostat Type _____

   NOTE: See installation instructions.

3. Install low voltage thermostat on a furnace with air conditioner.

   Furnace Model # _____

   Air Conditioner Model # _____

   Thermostat Type _____

   NOTE: See installation instructions.

I. Answer the following questions:

1. What is a heat anticipator?

2. What is the purpose of a heat anticipator?

3. What is overshoot and system lag in reference to a heat anticipator?

4. What is the purpose of a cooling anticipator?

5. How do you set a heat anticipator on a thermostat?

6. How is a heating anticipator connected in a thermostat?

1. Set heat anticipator on a gas heating system.

   Gas Furnace Model # _____

   Type Thermostat _____

   Heat anticipator setting _____

2. Set heat anticipator on an electric furnace.

   Electric Furnace Model # _____

   Type Thermostat _____

   Heat Anticipator Setting _____

3. Examine and check cooling anticipator on air conditioning system.

   Air Conditioner Model # _____

   Type Thermostat _____

   Condition of Anticipator _____

The instructor will assign the equipment needed to install both one and two stage heating and cooling thermostats. Record the required information into the charts below of the equipment utilized.

1. Install a two stage cooling and two stage heating thermostat on system in shop assigned by the instructor.

   Heating Unit Model # _____

   Available Stages _____

   Type of Thermostat _____

   Cooling Unit Model # _____

   Differential between Stages _____

2. Install one stage cooling and two stage heating thermostat on heat pump in the shop.

   Heat Pump Model # _____

   Type of Thermostat _____

   1st Stage Heat Load _____

   2nd Stage Heat Load _____

I. Install a clock thermostat on a gas furnace with electric air-conditioner in the shop.

Furnace Model # _____

Air Conditioner Model # _____

I. Troubleshoot and repair if possible 5 air conditioning and heating systems with thermostat problems. (Be specific - "bad thermostat" is not a good enough answer).

System	Model No.	Faults
Unit #1		
Unit #2		
Unit #3		
Unit #4		
Unit #5		

MAJOR BLOCK Electricity **NAME** _____

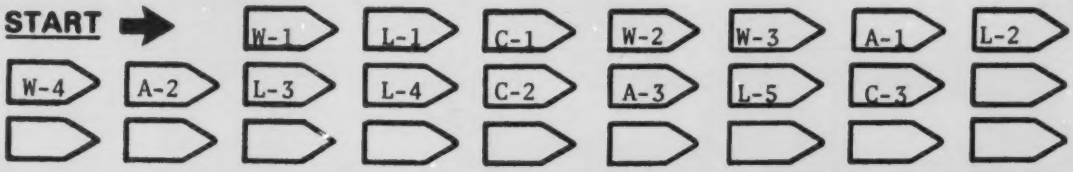
TASK Electrical Components

UNIT Installing and Checking Pressure Switches **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-23

OBJECTIVE(S)

Install, set and troubleshoot both high pressure switches (HPS) and low pressure switches (LPS).



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-23a
W-2	Assignment Sheet EL-23a
W-3	Information Sheet EL-23a
W-4	Information Sheet EL-23b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-23a
A-2	Slide Set EL-23b
A-3	Slide Set EL-23c
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-23a
L-2	Job Sheet EL-23b
L-3	Job Sheet EL-23c
L-4	Job Sheet EL-23d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

The instructor will provide an assortment of pressure switches. Identify switches by number and classify according to function, range, etc. Record the required information into the table below according to the unique capabilities of each switch.

Pressure Switch #	Type (LPS or HPS)	Range (PSI)	Setting		Switching Action (Opens or Closes on Rise)
			Cut In	Cut Out	
1.					
2.					
3.					
4.					
5.					
6.					

I. Answer the following questions:

1. What is a pressure switch?

2. What would be the switching action of a High pressure switch used as a safety control?

3. What would be the switching action of a Low pressure switch used as a safety device?

4. Define the following terms in their relationship to pressure switches:

   a. differential _____

   _____

   b. cut-in _____

   _____

   c. cut-out _____

   _____

   d. range _____

   _____

Pressure Switches Used as Safety Controls

One of the most important uses of pressure controls in a refrigeration or air conditioning system is a safety device. From the study in basic refrigeration it is evident that there are certain safe operating conditions of a refrigeration system in regards to the suction and discharge pressure. If a refrigeration system is operating with a lower than normal suction pressure or a higher than normal discharge pressure, damage can be done to the compressor. Since the compressor is the most expensive part of a refrigeration system, it is imperative that it be protected properly. The High pressure switch and Low pressure switch will insure the safe operation of the compressor.

There are many reasons why the suction pressure might be lower than normal such as,

1. low refrigerant charge
2. faulty metering device
3. no air flow across the coil, or other problems

High discharge pressure can be caused by,

1. overcharge of refrigerant
2. condenser problems
3. restriction in high side, or others.

Whatever the reasons for dangerous pressure reading on the high side or low side of a system, the compressor should be cut off to prevent damage.

The pressure in a refrigeration system changes with each refrigerant used in the system. For example, the operating pressure of an F-12 system is lower than that of an F-22 or F-502 system. The mechanic must know which type of refrigerant is used in a system to set or troubleshoot a High pressure switch or Low pressure switch for a safety device.

When setting a Low pressure switch or High pressure switch for a safety device, always follow the manufacturer's specifications if they are available. If specifications are not available, always use some type of guide when setting the control. The High pressure switch usually can be set according to the guide without any concern for the application of the system, but do change from water to air cooled units. The application of the system, however, does affect the Low pressure switch setting. For example, the Low pressure switch could not be set the same for an air conditioning system as for a freezer. The correct operating suction must be considered. Illustrations in the reading assignment can be used as guides for setting of Low pressure switch and High pressure switch when they are used for safety controls.

1. Set the low pressure switch on the following three units to be used as safety control.

	Model No.	Setting
Unit #1		
Unit #2		
Unit #3		

2. Set the high pressure switch on the following three units to be used as a safety control.

	Model No.	Setting
Unit #1		
Unit #2		
Unit #3		

3. Set the dual pressure switch on Unit # _____ to operate as a safety control.

   High Pressure Setting _____

   Low Pressure Setting _____

4. A. Install a High Pressure Switch on a unit and set for safety control.

   B. Install a Low Pressure Switch on a unit and set for safety control.

Pressure Switch Used as Operating Control

There are many applications used in industry where a low pressure switch is used as an operating control. In commercial refrigeration, the low pressure switch is often used as an operating control for a walk-in-cooler or a commercial refrigerator. On some large air conditioning systems, the low pressure switch is used to operate cylinder unloaders. The evaporator temperature directly corresponds to the pressure in the low side of the system. Therefore, if a low pressure switch is set correctly, it can also control the temperature in medium temperature applications.

It is fairly simple to set a low pressure switch to control an unloader in an air conditioning system. The mechanic knows that if the unit is charged correctly, the lower the suction pressure, the smaller the load; and the higher the suction pressure, the larger load. To set a pressure switch to control an unloader, the mechanic should set the pressure switch at about normal operating suction pressure with a differential of about 10 psig.

When a mechanic must set a low pressure switch as an operating control on a walk-in-cooler or a commercial refrigerator, calculate what the pressure should be for the temperature inside the box. For example, if a mechanic wishes to maintain 35° in a walk-in-cooler, the suction pressure should be somewhere around 20 to 25 psig depending upon the length of the refrigerant lines. The differential of the low pressure switch should be set where you maintain a 5° temperature in the cooler and so the unit will not short cycle.

It is often difficult to set the low pressure switch for an operating control. Most mechanics will have to set the low pressure switch and return to reset after the box has pulled down. The mechanic should never leave a unit until he is absolutely certain it is operating correctly.

1. Set the low pressure switch on a walk-in-cooler to maintain a 35° fahrenheit temperature with a plus or minus 5° fahrenheit swing and no short cycling.

2. Set the low pressure switch on commercial refrigerator to maintain a 45° fahrenheit temperature with a plus or minus 5° fahrenheit temperature swing and no short cycling.

1. Set the high pressure switch to maintain head pressure of condensing unit at 200 psig.

   A. Model No. _____

2. Set the low pressure switch to control cylinder unloaders. Set to unload at 62 psig and load at 70 psig suction pressure.

   A. Model No. _____

Troubleshoot five pressure switches and determine the problem. List the fault and record the pressures in the chart below.

	FAULT	PRESSURES	
Unit #1	_____	S.P.	_____
		D.P.	_____
Unit #2	_____	S.P.	_____
		D.P.	_____
Unit #3	_____	S.P.	_____
		D.P.	_____
Unit #4	_____	S.P.	_____
		D.P.	_____
Unit #5	_____	S.P.	_____
			_____

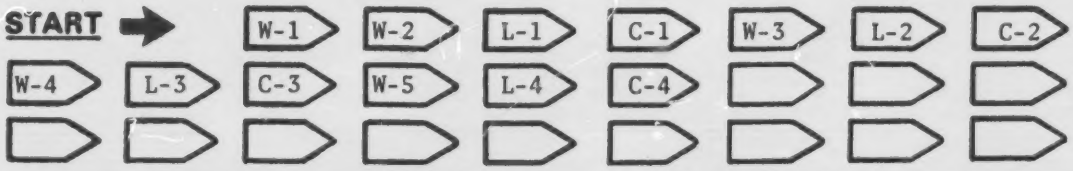
MAJOR BLOCK Electricity **NAME** _____

TASK Electrical Components

UNIT Troubleshooting an overload **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-24

OBJECTIVE(S) Locate faulty overload devices



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-24a
W-2	Assignment Sheet EL-24a
W-3	Information Sheet EL-24a
W-4	Information Sheet EL-24b
W-5	Information Sheet EL-24c
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-24a
L-2	Job Sheet EL-24b
L-3	Job Sheet EL-24c
L-4	Job Sheet EL-24d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

1. Answer the following questions:

   1. What is the purpose of an overload?

   2. What is the most simple type of overload in use today?

   3. What is the difference between a line break overload and a pilot duty overload?

   4. How does a magnetic overload sense an overload?

   5. Where is an internal compressor overload mounted?

I. Identify the overloads assigned by the instructor and list them below:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

II. Locate five overloads on equipment and list the model # of the equipment and the type of overload.

	Model No.	Type Overload
#1		
#2		
#3		
#4		
#5		

THERMAL OVERLOADS

Thermal overloads are in wide use in the industry. Most types of equipment use some type of thermal overload in small motors. The thermal overload senses the temperature of an electric motor through the temperature directly or by means of a thermal element that is mounted in the overload close to a bimetal that will warp if warmed to overload condition. When the bimetal warps a set of contacts are opened stopping the load. Fig. 8.17 and 8.18 in Text #3 (page 180) show this type of overload. Most overload devices sense an overload through an element that transfers the current draw into heat which warms a bimetal element. However, some overloads are attached directly to the compressor or motor which uses both heat and current draw.

A thermal overload can be line break, which breaks the main power supply to a motor, or pilot duty which would open a set of contacts in the control circuit to stop the motor. Fig. 8.15 in Text #3 (page 179) shows a line break overload. Notice that this overload has 3 wires and protects the start and run winding of a motor. A two wire line break overload would protect both windings, but only through the common terminal of a compressor.

A line break overload is easy to troubleshoot because it is either open or closed. This can be checked with an ohmmeter. A line break overload can open and close at inaccurate amp draws. If this problem is suspected, check the amp draw of the motor. If the overload opens at a faulty amp draw the mechanic should change the overload unless the body of the compressor is extremely hot, then the overload is operating properly.

A pilot duty overload senses an overload in the same method as a line break overload, but opens up a set of contacts that are connected in series with the control circuit which would stop the motor.

To troubleshoot a pilot duty overload a mechanic must check the contacts and the element. The element is the large set of terminals on the overload and should read little or no resistance. In checking the contacts, they should be either open or closed. The contacts are the uppermost terminals on the overload. Like the line break thermal overload, the overload can malfunction by opening when it should be closed. A mechanic can check this with a clamp on amemeter.

1. Procedure for Troubleshooting Thermal Overloads

   A. Line Break Thermal Overload

      1. Check the contacts of the overload

         a. If overload is open check the voltage, compressor, and starting components.

         b. If all of the above components are good attempt to start motor after overload closes. (If compressor or motor body is warm remove overload from compressor or motor shell)

         c. If the contacts in the overload open again, check the compressor or motor.

         d. If motor is good check amp draw of motor.

         e. If amp draw is correct change overload.

         f. If amp draw is high further check of compressor is required.

         g. Make sure the contacts or the element of the overload are not burned out.

         h. If the overload is bad, change with correct replacement.

   B. Pilot Duty Overload

      1. Check contacts of overload

         a. If contacts are open the same check as performed in A should be followed.

         b. Check element of overload with ohmmeter.

II. Troubleshoot 3 Line Break Overloads

   Condition of Overloads

   #1

   #2

   #3

III. Troubleshoot 3 Pilot Duty Overloads

Condition of Overload

#1

#2

#3

IV. Replace Thermal Overload on Compressor

Magnetic Overloads

Magnetic overloads were more widely used in the past than they are at the present time. Another name for the magnetic overload is the Huseman relay. The magnetic overload is made up of a set of pilot duty contacts with an element. The element consists of a movable metal core in a tube filled with oil. Surrounding the metal tube is a coil of wire. Inside the metal tube is a plunger. When the magnetic field created by the coil becomes great enough to show an overload the plunger will be pulled through the oil opening a set of contacts stopping the compressor.

In a magnetic overload, the pilot duty contacts, the coil, or the plunger can be faulty. To check the contacts of a magnetic overload the mechanic should use an ohmmeter and determine whether the contacts are open or closed. There is a possibility that the coil could be broken this can be checked with an ohmmeter. The ohm reading should be 0 Ohms. An infinite reading would indicate a broken or burned coil. Also, at times the plunger of the overload will wear down and become too small to slowly move in the cylinder thus allowing the contacts to open on normal start up of a motor.

The same conditions can exist in a magnetic overload that exist in other pilot duty contacts and they can be checked the same way.

I. Procedure for Troubleshooting a Magnetic Overload

1. Check the contacts of the magnetic overload

   a. If contacts are open make certain the motor is overloaded.

   b. If motor is not overloaded check possible overload malfunction.

2. Check coil of overload

   a. If load will not operate check coil of overload.

   b. If coil is open change overload.

II. Troubleshoot three Magnetic Overloads.

Condition of Overload

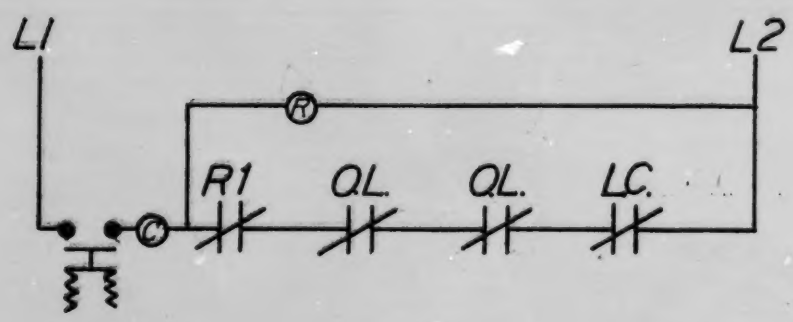
#1

#2

#3

III. Replace a thermal overload with a magnetic overload.

IV. Install lock out relay to prevent, short cycling of load (use diagram below).



TH-Cooling Thermostat
Ⓒ-Compressor Contactor coil
O.L.-Motor Overload Protector Contacts
L.C.-Limit Control Contacts
Ⓡ-Lock Out Relay Coil
R1-Lockout Relay Normally Closed Contacts

The most common type overload used on compressors installed in residential units is an internal line break overload. This type overload has become popular primarily during the last 5 to 10 years. There is also an internal thermostat which is a pilot duty and has separate external connections while the in line internal overload is connected internally.

There are many more kinds of specialized overloads which are used in the industry on large equipment and sometimes with smaller units. It would be impossible to discuss this type overload and if you have questions concerning them consult a service manual.

1. Procedure for Checking Internal Overload (Line Break)

   A. The internal overload is connected in series with the common of the compressor.

   B. If the compressor is hot to touch give the overload time to close before condemning the compressor.

   C. If the compressor windings check open and after it cools, the overload was open.

   D. If an internal overload is bad the compressor winding will check open.

   E. If an internal overload is bad the compressor must be changed.

II. Troubleshoot two compressors with internal overloads

   Condition of Overload

   #1

   #2

MAJOR BLOCK Electricity **NAME** _____

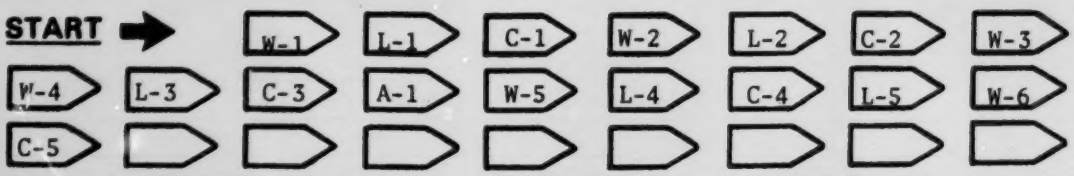
TASK Electrical Components

UNIT Installing and Checking Miscellaneous Controls **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-25

OBJECTIVE(S)

Install and Check Electro-Mechanical Controls



WRITTEN ASSIGNMENT(S)

W-1	Information Sheet EL-25a
W-2	Information Sheet EL-25b
W-3	Text Assignment EL-25a
W-4	Text Assignment EL-25b
W-5	Text Assignment EL-25c
W-6	Assignment Sheet EL-25a
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-25a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

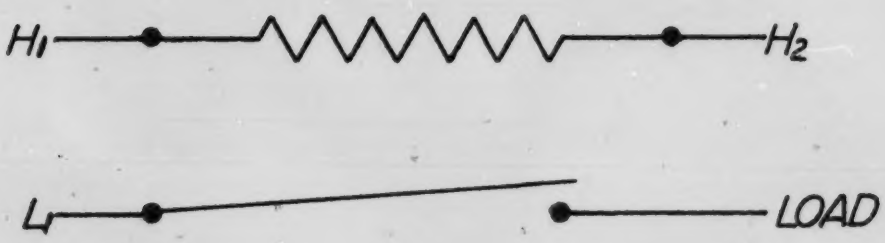
LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-25a
L-2	Job Sheet EL-25b
L-3	Job Sheet EL-25c
L-4	Job Sheet EL-25d
L-5	Job Sheet EL-25e
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

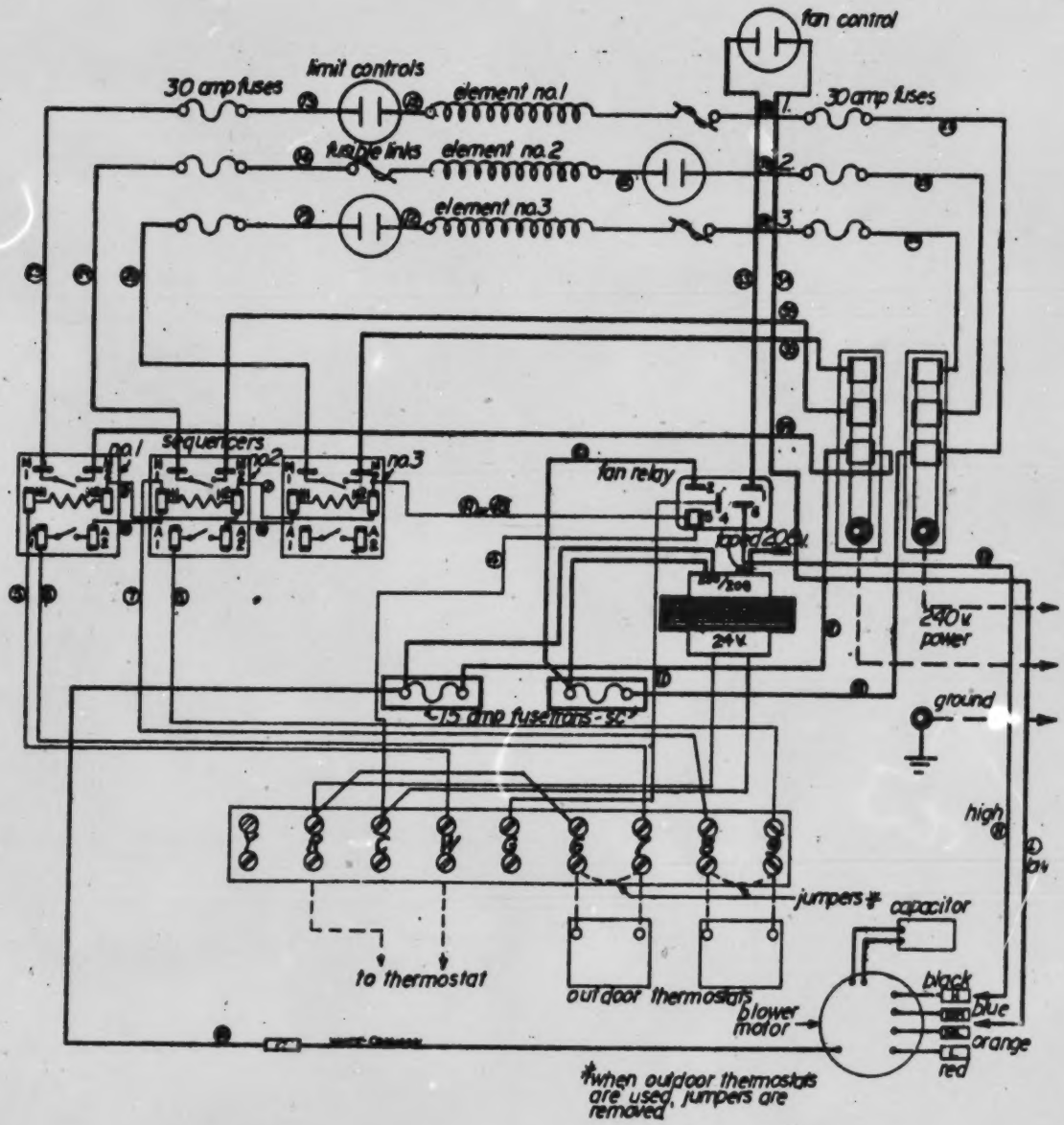
C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	
C-7	
C-8	
C-9	

A sequencer is an electrical device that is designed to operate a load such as an electric heater in an electric furnace. A sequencer is designed with a bi-metal element connected to a set of contacts that is opened and closed by a heater mounted close to the bi-metal element. A wiring diagram for a sequencer is shown below:



When voltage is applied to the heater which can be 24V, 110V or 230V, it will increase in temperature causing the bi-metal to warp, closing the set of contacts controlling the load.

Many times sequencers will have more than one set of contacts. Sequencers are in common use on electric furnaces. The diagram below is of an electric furnace incorporating sequencers to start the heaters and the fan motor.


fan control
limit controls
30 amp fuses
element no.1
30 amp fuses
fusible links
element no.2
element no.3
sequencers
no.1
no.2
no.3
fan relay
240v. power
ground
24v.
high
jumpers*
capacitor
to thermostat
outdoor thermostats
blower motor
black
blue
orange
red
*when outdoor thermostats are used, jumpers are removed

Sequencers are easy to install on a system, especially if they are of the same manufacturer. If a replacement sequencer is of the same manufacturer and the same model number, it can be installed exactly like the sequencer which was removed. If the sequencer is different, the mechanic should pay close attention to the heater and contacts of the sequencer. These terminals will usually perform the same function even though the sequencers are not exactly alike.

When troubleshooting a sequencer, the mechanic need only check the heater and the contacts. If the heater is bad in a sequencer, it will usually be open. The contacts of a sequencer will not close if the heater is faulty. The contacts of a sequencer could be faulty because the bi-metal element is bad; or, in some cases, the contacts may be completely burned out. Most electric resistance heaters pull a large amp draw, thus causing the contacts to burn out on occasion.

A service mechanic can check the heater with an ohmmeter. If the heater is bad, it will show open, and if good, the heater will show continuity. The contacts of a sequencer are harder to check because they will not close unless the heater is energized. If a mechanic is attempting to check the contacts, he should make certain the heater is energized. If the heater is energized, the contacts should be closed within 45 seconds after it is energized. If the contacts do not close, the contacts or the bi-metal element are at fault and the sequencer should be replaced.

I. Install the same type of sequencer on an electric furnace.

II. Install a sequencer on an electric furnace different from original manufacturer.

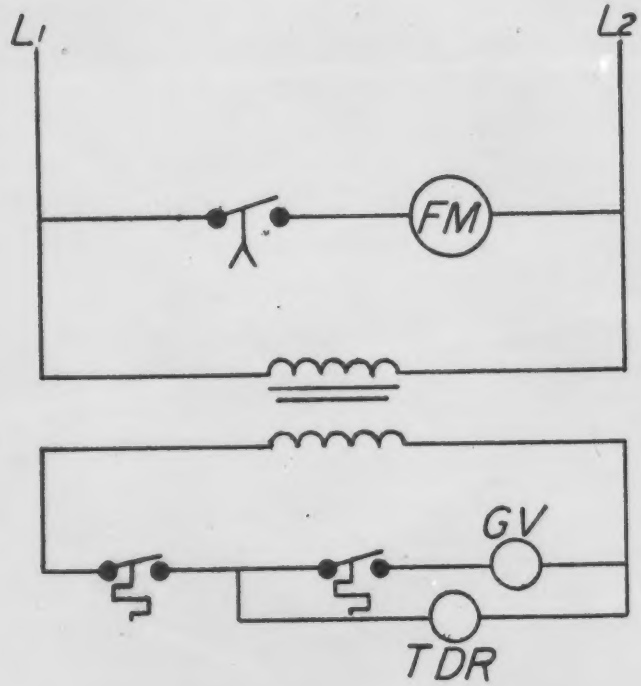
III. Troubleshoot two sequencers on an electric furnace.

	Fault	Sequencer
#1		
#2		

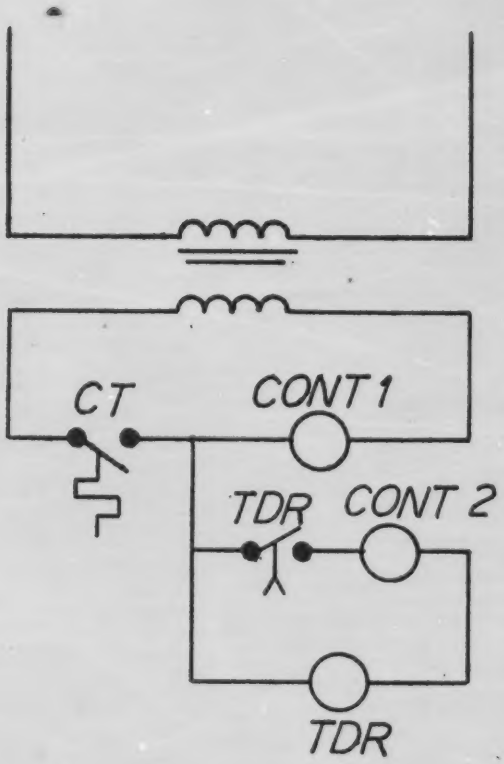
Time Delay Relays

I. Below are two diagrams showing the application of time delay relays.

A. This is the diagram of a furnace using a time delay relay to start the fan motor after the furnace is warmed up.



B. This diagram shows two condensing units connected in parallel to one thermostat. The time delay relays are used to prevent both condensing units from starting at the same time.



I. Install a time delay relay on a fan on a gas furnace to delay the fan motor starting.

II. Troubleshoot two time delay relays on equipment.

Fault with Time Delay Relay

#1

#2

I. Install a humidistat on a humidifier in the shop.

I. Install an oil safety switch on a compressor in the shop. (Use installation instructions with switch.)

II. Check oil safety switch by closing oil pressure to switch. (Switch should drop compressor out of circuit.)

III. Troubleshoot oil safety switch.

I. Install a seven-day time clock on an air conditioning system. Set as follows:

	On	Off
Monday	6:00 AM	4:00 PM
Tuesday	6:00 AM	4:00 PM
Wednesday	6:00 AM	12:00 PM
Thursday	6:00 AM	4:00 PM
Friday	6:00 AM	4:00 PM
Saturday	6:00 AM	11:00 PM
Sunday	(Off all day)	

I. Answer the following questions:

1. What is a sequencer?

2. What is the most common application of the sequencer in the industry?

3. What is the purpose of a time delay relay?

4. Under what circumstance would you use a time delay relay?

5. What is the purpose of a humidistat?

6. Draw a diagram using a humidistat to control a 110V humidifier.

7. What is the purpose of an oil safety switch?

8. How does an oil safety switch work?

9. What is the purpose of a time clock?

10. How can a time clock conserve energy?

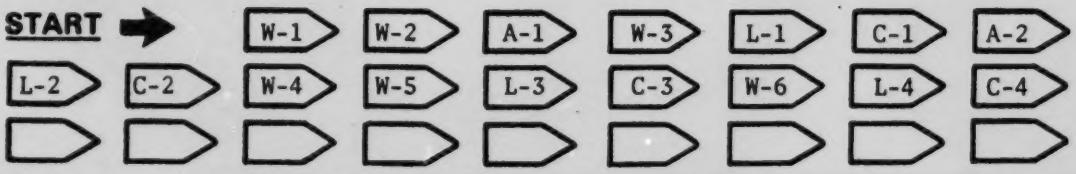
MAJOR BLOCK Electricity **NAME** _____

TASK Electrical Components

UNIT Troubleshooting Magnetic Starters **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-26

OBJECTIVE(S)



WRITTEN ASSIGNMENT(S)

W-1	Information Sheet EL-26a
W-2	Text Assignment EL-26a
W-3	Assignment Sheet EL-26a
W-4	Information Sheet EL-26b
W-5	Text Assignment EL-26b
W-6	Information Sheet EL-26c
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-26a
A-2	Slide Set EL-26b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-26a
L-2	Job Sheet EL-26b
L-3	Job Sheet EL-26c
L-4	Job Sheet EL-26d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Magnetic Starter Principles

Magnetic starters are in wide use in the Heating and Air Conditioning industry. A magnetic starter is similar to a contactor with the exception of having overload protection. Magnetic starters are manufactured in several different sizes. The following chart shows the sizes available.

The power circuit of a magnetic starter includes the fixed and moveable contacts with the element portion of the overload. The number of contacts is determined by the application. For example, a 1 Ø system will need 2 poles and a 3 Ø system will require 3 poles.

The power circuit contacts handle the motor load. The starter must be sized correctly to prevent overheating of the contacts. See the sizing chart on the next page for the correct size magnetic starter.

The control circuit of a magnetic starter is composed of the magnetic coil, the overload contacts, a reset device, and a set of pilot contacts. When voltage is applied to the coil, the starter will close. The following drawing shows the starter, and schematic.

The sizing chart below is reprinted through the courtesy of Furnas Electric Company, Batavia, Illinois.

SIZE	HORSEPOWER	MOTOR SPEED R.P.M.	FULL LOAD MOTOR AMPS.	HEATER CODE
00	3/4	3600	1.98- 2.11	H18
		1800	2.28- 2.43	H20
		1200	2.44- 2.94	H21
		900	4.10- 4.55	H23
	1	3600	2.44- 2.94	H21
		1800	2.95- 3.22	H22
		1200	3.23- 3.67	H23
		900	4.10- 4.55	H25
	1 1/2	3600	4.10- 4.55	H25
		1800	4.10- 4.55	H25
		1200	5.02- 5.54	H27
		900	5.55- 6.12	H28
0	2	3600	5.33- 5.89	H28
		1800	5.90- 6.69	H29
		1200	6.70- 7.39	H30
		900	7.40- 8.22	H31
	3	3600	8.23- 9.29	H32
		1800	8.23- 9.29	H32
		1200	9.30-10.5	H33
		900	9.30-10.5	H33
1	5	3600	13.0- 14.4	H37
		1800	13.0- 14.4	H37
		1200	14.5- 15.4	H38
		900	15.5- 16.4	H39
	7 1/2	3600	18.7- 21.2	H41
		1800	18.7- 21.2	H41
		1200	18.7- 21.2	H41
		900	23.1- 26.1	H43
1 3/4	10	3600	23.1- 26.1	H43
		1800	23.1- 26.1	H43
		1200	26.2- 30.3	H44
		900	30.4-32.3	H45
2	15	3600	37.8- 42.4	H46
		1800	37.8- 42.4	H46
		1200	37.8- 42.4	H46
		900	37.8- 42.4	H46
2 1/2	20	3600	47.5- 52.4	H49
		1800	47.5- 52.4	H49
		1200	52.5- 55.4	H50
		900	55.5- 60.0	H51
3	25	1800	57.2- 62.1	H49
		1200	62.2- 65.4	H50
		900	65.5- 72.2	H51
		600	72.3- 77.1	H52
	30	1800	65.5- 72.2	H51
		1200	72.3- 77.1	H52
		900	72.3- 77.1	H52
		600	82.3- 90.0	H78
3 1/2	40	1800	94.2 -101	H77
		1200	94.2 -101	H77
		900	102 -108	H78
		600	109 -118	H79
4	50	1800	109 -118	H79
		1200	119 -136	H85
		900	119 -136	H85
4 1/2	60	1800	132 -142	H19
		1200	143 -154	H20
		900	143 -154	H20
	75	1800	171 -189	H22
		1200	171 -189	H22
		900	171 -189	H22
5	100	1800	220 -248	H24
		1200	220 -248	H24
		900	220 -248	H24
6	200	1800	454 -480	H24
		1200	454 -480	H24
		900	454 -480	H24

I. Answer the following questions:

1. What is the difference between a contactor and magnetic starter?

2. What size magnetic starter would be used on a 3 Ø 10 Horsepower motor?

3. What are the basic components in the control portion of a magnetic starter?

4. Draw a schematic diagram of a magnetic starter.

I. Disassemble a magnetic starter and identify the parts.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

1. Draw a wiring diagram of a magnetic starter using a toggle switch to control the starter.

2. Install a magnetic starter to operate a 3 Ø motor using a toggle switch as the controlling element.

3. Install a magnetic starter to operate a 3 Ø motor using a 24 volt thermostat.

The following Information Sheet on Control Circuit Diagrams (push buttons) is reprinted through the courtesy of Furnas Electric Company, Batavia, Illinois.

CONTROL CIRCUIT DIAGRAMS

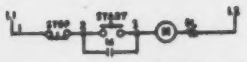


Fig. 1. Three Wire Control Giving Low Voltage Protection Single Two Button Pushbutton Station

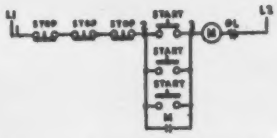


Fig. 2. Three Wire Control Giving Low Voltage Protection Multiple Two Button Pushbutton Stations

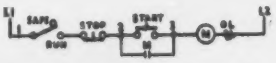


Fig. 3. Three Wire Control Giving Low Voltage Protection with Safe-Run Selector Switch

Fig. 4. Three Wire Control for Jog or Run Using Start-Stop Pushbuttons and Jog-Run Selector Switch

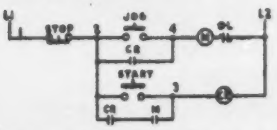


Fig. 5. Control for Jogging-Start-Stop All with Push-buttons

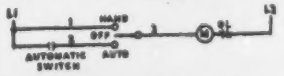


Fig. 6. Two Wire Control Giving Low Voltage Release Only Using Hand-Off-Auto Selector Switch

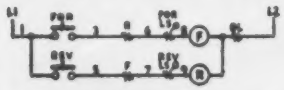


Fig. 7. Two Wire Control for Reversing Jogging. Using Single Two Button Pushbutton Station

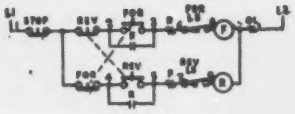


Fig. 8. Three Wire Control for Instant Reversing Applications Using Single Three Button Pushbutton Station

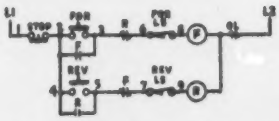


Fig. 9. Three Wire Control for Reversing Using Single Three Button Pushbutton Station

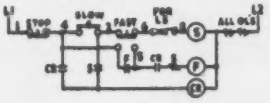


Fig. 10. Control for Two Speed with a Compelling Relay to Insure Starting on Slow Speed

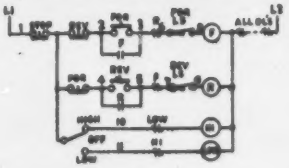


Fig. 11. Control for Two Speed Reversing Starter Forward, Reverse, Stop, with High, Low Selector Switch

Fig. 12. Selector Push Contacts as shown for "Run" (three wire operation) rotate switch sleeve and selector contact opens between "J" and "Stop" button (two wire operation).

Furnas Electric
Catalog- August 1, 1972

1. Install a magnetic starter on a 3 Ø motor and operate motor with a stop-start push button switch. (See push button control diagrams on Information Sheet).

Information Sheet EL-26c

The following information sheet on Troubleshooting Electric Motor Controls is reprinted through the courtesy of Furnas Electric Company, Batavia, Illinois.

TROUBLESHOOTING ELECTRIC MOTOR CONTROLS

Varying factors such as temperature, humidity and atmosphere may adversely affect the performance of motor controls. Misapplication of a control also may lead to serious trouble and is often regarded as a major cause of motor control problems. All these factors must be taken into consideration when a device does not function properly.

It is important to make a complete mechanical check of motor control equipment before and after installation. Damaged or broken parts can usually be found easily and quickly, then replaced if necessary. Visual checks are one of the trouble-shooter's most valuable tools. Controls leave the factory fully inspected, but mishandling at a later time could affect performance.

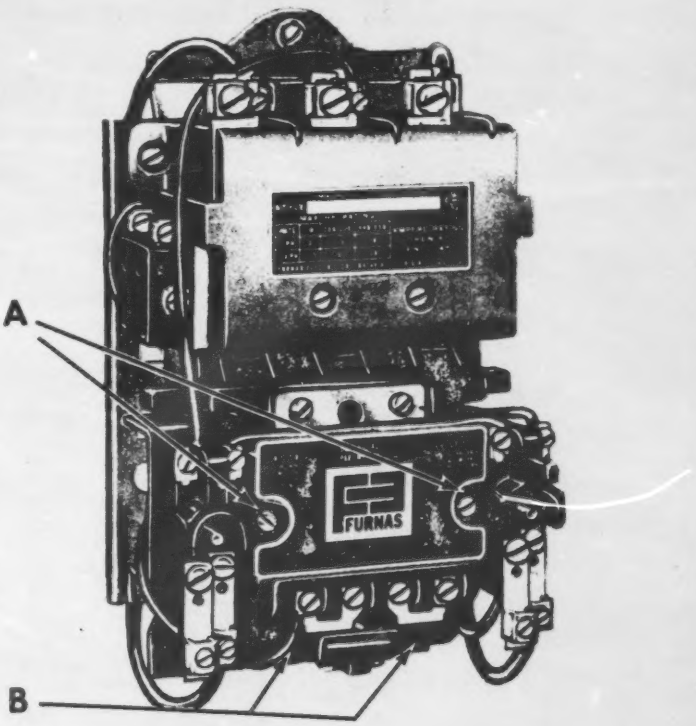
Quiet operation of magnetic contactors and starters depends upon accurately aligned magnets as well as proper seating of same. It follows that this noise factor increases with increased size of ground and polished pole faces, especially size 2 and larger.

Occasionally when these larger units are handled during shipping or installation, the armature may be knocked out of line with the magnet. As a result the device will hum when energized. The greater the degree of misalignment, the louder the hum. Hum in no way harms the operation of the device but may be objectionable especially if quiet operation is important, such as in an office building or hospital.

To determine the cause of the noisy armature, follow these procedures:

1. Inspect to see if the correct coil voltage is applied to the coil. If the control is equipped with a dual voltage coil, make sure connections conform to those in the wiring diagram.

2. Inspect the ground pole faces to see if they are free of dirt and rust. Clean if necessary. Dirt can be removed with a small brush such as a tooth brush. Never file the pole face areas since these surfaces have been precision ground at the factory.



3. Check the operation after performing steps 1 and 2. If the noise is still objectionable, proceed as follows:

4. Loosen Screws "A", (see illust.). With this screw loose, but not removed, the Armature "B" may be moved slightly in the slots. Only a very small movement is necessary to rotate or adjust the armature into alignment with the magnet. Energize the magnet and retighten the screws. Several attempts may be necessary before the best alignment and the quietest operation are attained

5. Check the tightness of all screws, and if the noise persists, change the magnet assembly.

Point-by-point mechanical and electrical checks are always wise. The following procedures should provide quick answers to seemingly difficult troubleshooting problems.

Problems	Possible Cause	Solution
I — Magnetic and Mechanical Parts		
(a) Noisy Magnet (Humming)	1. Misalignment or mismating of magnet pole faces.	1. Realign or replace magnet assembly.
	2. Foreign matter on pole face. (dirt, lint, rust, etc.)	2. Clean (but do not file) pole faces and realign if necessary.
	3. Low voltage applied to coil.	3. Check system and coil voltage. Observe voltage variations during start-up time.
(Loud Buzz)	4. Broken shading coil.	4. Replace shading coil and/or magnet assembly.
(b) Failure to Pick-up and Seal-in.	1. Low Voltage.	1. Check system voltage, coil voltage, and watch for voltage variations during starting.
	2. Wrong magnet coil or wrong connection.	2. Check wiring, coil nomenclature, etc.
	3. Coil open or shorted.	3. Check with an ohmmeter and when in doubt, replace.
	4. Mechanical obstruction.	4. Disconnect power and check for free movement of magnet and contact assembly.
(c) Failure to Drop-out. (See Addendum also)	1. "Gummy" substance on pole faces or magnet slides.	1. Clean with non-volatile solvent, degreasing fluid, possibly gasoline (with caution).
	2. Voltage to coil not removed.	2. Shorted seal-in contact (exact cause found by checking coil circuit).
	3. Worn or rusted parts causing binding.	3. Clean or replace worn parts.
	4. Residual magnetism due to lack of air gap in magnet path.	4. Replace any worn magnet parts or accessories.
II — Contacts		
(a) Contact Chatter (Source probably from magnet assembly)	1. Broken shading coil.	1. Replace assembly.
	2. Poor contact continuity in control circuit.	2. Improve contact continuity or use holding circuit interlock (3 wire control).
	3. Low voltage.	3. Correct voltage condition. Check momentary voltage dip during starting.

Problems	Possible Cause	Solution
(b) Welding	1. Abnormal inrush of current.	1. Use larger contactor or check for grounds, shorts or excessive motor load current.
	2. Rapid jogging.	2. Install larger device rated for jogging service or caution operator.
	3. Insufficient Tip Pressure.	3. Replace contact springs; check contact carrier for deformation or damage.
	4. Low voltage preventing magnet from sealing.	4. Correct voltage condition. Check momentary voltage dip during starting.
	5. Foreign matter preventing contacts from closing.	5. Clean contacts with non-volatile solvent, contactors, starters, and control accessories used with very small current or low voltage, should be cleaned with solvent and then with acetone to remove the solvent residue.
	6. Short circuit.	6. Remove short fault and check to be sure fuse or breaker size is correct.
(c) Short Contact Life or Overheating	1. Filing or dressing.	1. Do not file silver contacts. Rough spots or discoloration will not harm them or impair their efficiency.
	2. Interrupting excessively high currents.	2. Install larger device or check for grounds, shorts or excessive motor currents.
	3. Excessive jogging.	3. Install larger device rated for jogging or caution operator.
	4. Weak contact pressure.	4. Replace contact springs; check contact carrier for deformation or damage.
	5. Dirt or foreign matter on contact surface.	5. Clean contacts with non-volatile solvent.
	6. Short circuits.	6. Remove short fault and check to be sure fuse or breaker size is correct.
	7. Loose connection.	7. Clean and tighten.
	8. Sustained overload.	8. Install larger device or check for excessive motor load current.

Problems	Possible Cause	Solution
	9. Excessive wear.	9. Higher than normal voltage will cause unnecessary force which may result in mechanical wear and bounce.
(d) Contacts Supports Discoloring	1. Loose connections.	1. Tighten hardware or replace.
NOTE: Any contact replacement should include a complete set replacement including the support springs, screws, etc.		
III — Coils		
(a) Open Circuit	1. Mechanical Damage	1. Handle and store coils carefully.
(b) Cooked Coil (Overheated)	1. Over voltage or high ambient temperature.	1. Check application and circuit. Coils will operate satisfactorily over a range of 85 to 110% of rated voltage.
	2. Incorrect coil.	2. Check rating and if incorrect, replace with proper coil.
	3. Shorted turns caused by mechanical damage or corrosion.	3. Replace coil.
	4. Undervoltage, failure of magnet to seal in.	4. Correct system voltage.
	5. Dirt or rust on pole faces increasing air gap.	5. Clean pole faces.
	6. Sustained low voltage.	6. Remedy according to local code requirements, low voltage system protection, etc.
IV — Overload Relays		
(a) Nuisance Tripping	1. Sustained Overload.	1. Check for motor or electrical equipment grounds and shorts, as well as excessive motor currents due to overload. Check motor winding resistance to ground.
	2. Loose connections.	2. Clean connections and tighten. This includes load wires and heater element mounting screws.
	3. Incorrect heater.	3. Check heater sizing and also check ambient temperature.
(b) Failure to trip-out (causing motor burn-out)	1. Mechanical binding, dirt, corrosion, etc.	1. Clean or replace.
	2. Incorrect heater or heaters omitted and jumper wires used.	2. Recheck ratings and heater size. Correct if necessary.

Problems	Possible Cause	Solution
	3. Wrong calibration adjustment.	3. Consult factory. Calibration adjustment is normally not recommended unless under factory supervision. It is customary to return units to factory for check and calibration.
V — Manual Starters		
(a) Failure to Operate (Mechanically)	1. Mechanical parts, including springs, worn or broken.	1. Replace parts as needed.
	2. Welded contacts due to misapplication or other abnormal cause.	2. Replace contacts and recheck operation.
(b) Trips Out Prematurely	1. Mctor overload, incorrect heaters, or misapplication.	1. Check conditions replace or adjust as needed.
VI — Timers		
A — Pneumatic		
(a) Erratic Timing	1. Foreign matter in valve.	1. Clean if at all possible or replace timing head complete and exchange unit with factory.
(b) Contacts Do Not Operate	1. Adjustment incorrect on time actuating screw.	1. Follow service bulletin instructions for desired adjustment.
	2. Worn or broken parts in switch assembly.	2. Replace defective parts.
B — Electronic Relay		
(a) Erratic Timing	1. Loose connections.	1. Check over unit visually.
	2. Timing relay worn out.	2. Plug in new tested relay.
	3. Defective components.	3. Check and replace if necessary.
(b) Timer Stops Operating	1. Mechanical relay.	1. Substitute good relay.
	2. Defective circuit components.	2. Check over unit visually and with a VTVM.* Replacement of circuit board probably better than repair if relay normal.
C — Electronic (Solid State)		*Vacuum Tube Voltmeter
(a) Erratic Timing	1. Loose connections.	1. Visually inspect all connections.
	2. Check external connections.	2. Check functions with VTVM in accordance with prescribed service instructions.

Problems	Possible Cause	Solution
(b) Timer Will Not Time Out	1. External connections.	1. Systematically check system.
	2. Check power supply to timer.	2. Fuses, etc.
	3. Initiation circuit open.	3. See Step 1.
	4. Contacts dirty.	4. See Step 1 and clean if necessary.
VII – Limit Switches		
(a) Broken Parts	1. Excessive over-travel of actuator.	1. Use resiliant actuator or operate within device tolerance.
(b) Inoperative	1. Switch actuator out of position or broken.	1. Inspect - repair - or replace.
	2. Lack of contact continuity.	2. Clean contacts; replace contact block if necessary.
VIII – Drum Controls		
(a) Poor Contact	1. Dirty rotor contacts and fingers.	1. Inspect contacts; if copper, burnish with 4-0 sandpaper until clean; if silver, use a suitable solvent. Check for approximately 3/64 inch finger movement.
	2. On horizontally mounted units dirt or other foreign matter could cause trouble.	2. Clean systematically with carbon tetrachloride and air.
(b) Sluggish or Hard Operating Switch	1. Dry bearings.	1. Lubricate bearings, sparingly.
	2. Worn parts.	2. Inspect carefully - replace any parts which may be worn.
IX – Pressure Switches		
(a) Pressure Switch Inoperative	1. Foreign matter in pressure sensing area.	1. Remove switch and clean opening.
	2. Contacts burned.	2. Clean contacts or replace them if necessary.
(b) Erratic Operation	1. Worn parts.	1. Inspect - adjust - replace.
	2. Diaphragm faulty.	2. Replace diaphragm.
(c) Very Frequent Operation	1. This likely due to a water-logged system.	1. Drain part of water from pressure tank and if possible, pump in about 4 lbs. air. (Remember air can be compressed but not liquid.)

Problems	Possible Cause	Solution
X — Pushbuttons		
(a) Button Inoperative (Mechanically)	1. Shaft has dirt or residue binding.	1. Check, clean, and clear.
	2. Contact board spring broken.	2. Replace contact board.
(Electrical)	3. Contaminated contacts and corrosion.	3. Clean.
Pushbutton - Pilot Lamp		
(a) No Light	1. Bulb out or burned out.	1. Replace with proper unit.
	2. Broken parts, wire, or transformer.	2. Inspect - repair - or replace.
	3. Short life of bulb due to excessive high voltage.	3. Replace with next higher voltage pilot lamp (brilliance may be reduced slightly).
	ADDENDUM	
Reversing Starters	(See I-c also.)	
(a) Failure to drop out or slow drop-out	1. Mechanical interlock binding.	1. Check interlock for free pivoting. New bushing or light lubrication may be required.

GENERAL INSPECTIONS

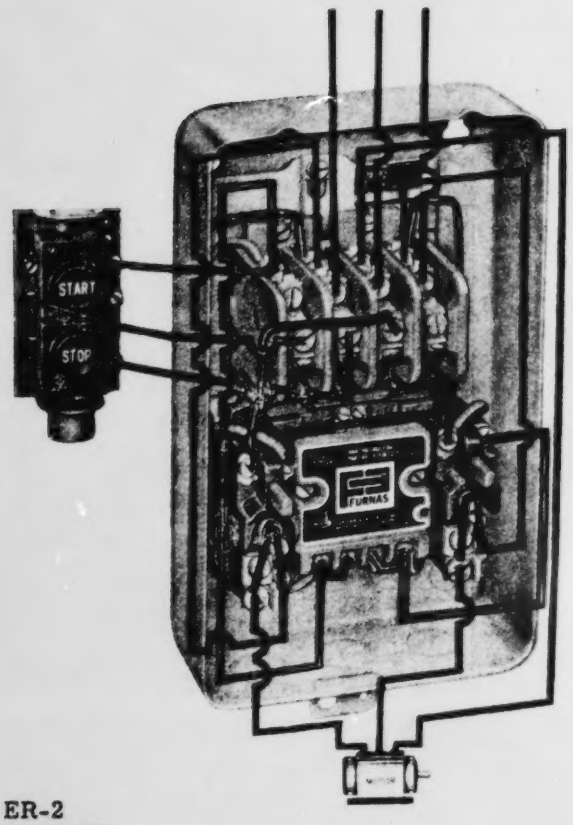
Inspect For	Check
Overloading	Installation to see that loads have not been stepped up beyond danger point.
Overheating	Location and load conditions of apparatus.
Wear	Each switch and unit for cleanliness and for condition of contacts and other parts.
Protection	Condition of fuses, heaters, circuit breakers. Make sure ratings are correct for load carried.
Safety	Condition of boxes and interlocking safety devices, and gaskets, if any.

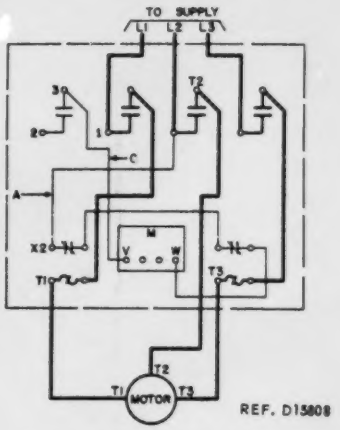
GOOD MAINTENANCE PROCEDURES

1. Keep equipment clean and dry.
2. Check contacts for trouble-causing conditions.
3. Clean contacts according to manufacturer's instructions.
4. Operate switches and controls periodically.
5. Make sure clearances are normal.
6. Replace worn or imperfect parts promptly.
7. Test handles, blades, crossbars for correct operation engagement and alignment.
8. Paint boxes and conduits periodically to prevent rust or corrosion.
9. Lubricate regularly, only where recommended.

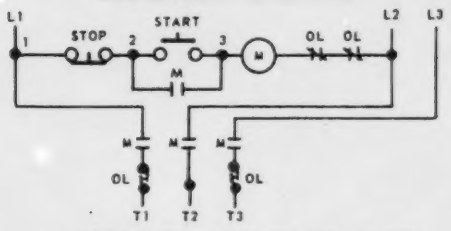
SYSTEM TROUBLESHOOTING

These pictures and diagrams show the construction of a magnetic starter control system. Troubleshooting should follow the suggestions given in these pages, but should also include a search for a more elusive trouble--open wiring.

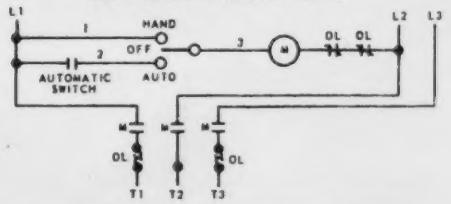




ELEMENTARY DIAGRAMS



Three Wire Control Giving Low Voltage Protection. Single Two Button Pushbutton Station.



Two Wire Control Giving Low Voltage Release Using Hand-Off-Auto Selector Switch.

I. Troubleshoot two magnetic starters. One with thermostat and one with push button control.

	Fault
#1	
#2	

MAJOR BLOCK Electricity **NAME** _____

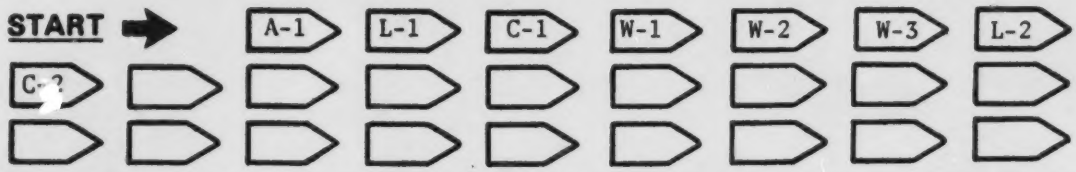
TASK Controls and Installation

UNIT Wiring Packaged Air Conditioners **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-27

OBJECTIVE(S)

Determine wire size and wire up a packaged air conditioner.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-27a
W-2	Information Sheet EL-27a
W-3	Text Assignment EL-27b
W-4	
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-27a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-27a
L-2	Job Sheet EL-27b
L-3	
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

1. Examine 4 packaged air conditioning units and complete the following form.

A. Unit #1
Model # _____
Voltage _____
Phase _____
Type of Condenser _____
Type of Heat _____

B. Unit #2
Model # _____
Voltage _____
Phase _____
Type of Condenser _____
Type of Heat _____

C. Unit #3
Model # _____
Voltage _____
Phase _____
Type of Condenser _____
Type of Heat _____

D. Unit #4
Model # _____
Voltage _____
Phase _____
Type of Condenser _____
Type of Heat _____

1. Read the installation instuctions of the two packaged units assigned by the instructor.

1. Size wire for packaged air conditioning #1 assigned by instructor.

   Unit Model # _____

   Voltage Characteristics _____

   Wire Size _____

2. Install power wiring to Unit #1.

3. Install control wiring to Unit #1.

4. Operate unit #1 and complete the data sheet.

   Unit Model # _____

   Voltage Characteristics _____

   Actual Voltage _____

   Comp Amp Draw _____

   CFM MP Draw _____

   IFM Amp Draw _____

   Total Unit Amp Draw_____

5. Size wire for packaged A/C #2 assigned by instructor.

   Unit Model # _____

   Voltage Characteristics _____

   Wire Size _____

6. Install power wiring to Unit #2.

7. Install control wiring to Unit #2.

8. Operate Unit #3 and complete the data sheet.

Unit Model # _____

Voltage Characteristics _____

Actual Voltage _____

Comp Amp Draw_____

CFM Amp Draw _____

IFM Amp Draw _____

Total Unit Amp Draw _____

MAJOR BLOCK Electricity **NAME** _____

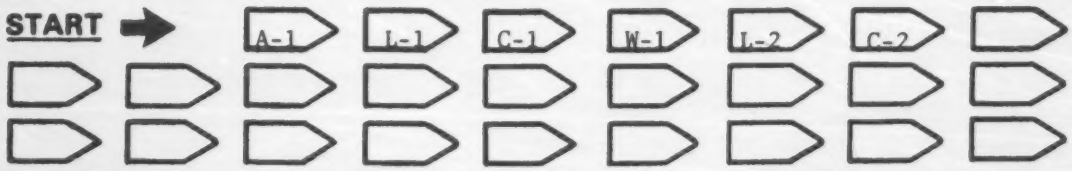
TASK Controls and Installation

UNIT Wiring Split System Air Conditioning **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-28

OBJECTIVE(S)

Determine wire size and wire up a split system air conditioning unit.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-28a
W-2 _____
W-3 _____
W-4 _____
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-28a
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-28a
L-2 Job Sheet EL-28b
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 _____
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

I. Examine four split system heating and air conditioning systems assigned by the instructor and complete the following data sheet on each system.

SYSTEM #1

Condensing Unit

Model #_____

Voltage and Phase _____

Air Moving Section

Model #_____

Fan Motor HP _____

Heat source (if any) _____

Air flow (horizontal, up-flow, counterflow) _____

SYSTEM # 2

Condensing Unit

Model #_____

Voltage and Phase _____

Air Moving Section

Model # _____

Fan Motor HP_____

Heat source (if any) _____

Air flow (horizontal, up-flow, counterflow)_____

SYSTEM #3

Condensing Unit

Model #_____

Voltage and Phase_____

Air Moving Section

Model #_____

Fan Motor HP _____

Heat source (if any) _____

Air flow (horizontal, up-flow, counterflow)_____

SYSTEM #4

Condensing Unit

Model #_____

Voltage and Phase_____

Air Moving Section

Model #_____

Fan Motor HP_____

Heat source (if any) _____

Air flow (horizontal, up-flow, counterflow)_____

I. Read the installation instructions for the two air conditioning or heating systems assigned by the instructor.

II. Size wire for air conditioner system (condensing unit) assigned by the instructor.

Condensing unit model # _____

Voltage characteristics _____

Wire Size _____

III. Install power wiring to both sections of system.

IV. Install control wiring to both sections of system.

V. Operate unit and complete the data sheet.

Condensing unit model # _____

Voltage characterists _____

Actual voltage _____

Amp. draw comp. _____

Amp. draw CFM _____

Blower coil model # _____

Voltage characteristics _____

Actual voltage _____

Fan motor amp. draw _____

VI. Size wire for heating and air conditioning system [condensing unit and furnace (fossil fuel, not electric)] assigned by your instructor.

Condensing unit model# _____

Voltage characteristics _____

Wire size _____

VIII. Install power wiring to both sections of system.

IX. Operate unit and complete the data sheet.

Condensing unit model # _____

Voltage characteristics _____

Actual voltage _____

Amp. draw comp. _____

Amp. draw CFM _____

Furnace model # _____

Voltage characteristics _____

Actual voltage _____

Furnace motor amp. draw _____

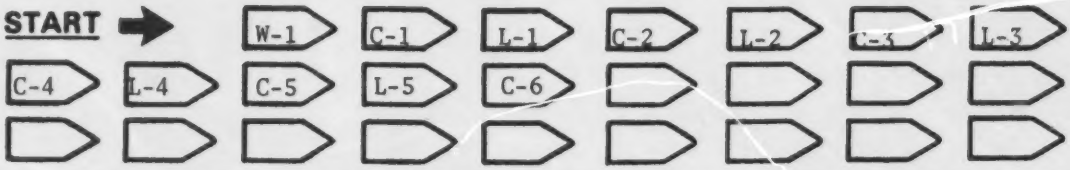
MAJOR BLOCK Electricity **NAME** _____

TASK Controls and Installation

UNIT Designing Control Panel (Basic) **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-29

OBJECTIVE(S) Design and assemble an operating control system for an air cooled packaged unit.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-29a
W-2 _____
W-3 _____
W-4 _____
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-29a
L-2 Job Sheet EL-29b
L-3 Job Sheet EL-29c
L-4 Job Sheet EL-29d
L-5 Job Sheet El-29e
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6 Instructor Check
C-7 _____
C-8 _____
C-9 _____

1. Obtain a 2'x2' piece of plywood which will be needed to attach components of the diagram in the previous reading assignment.

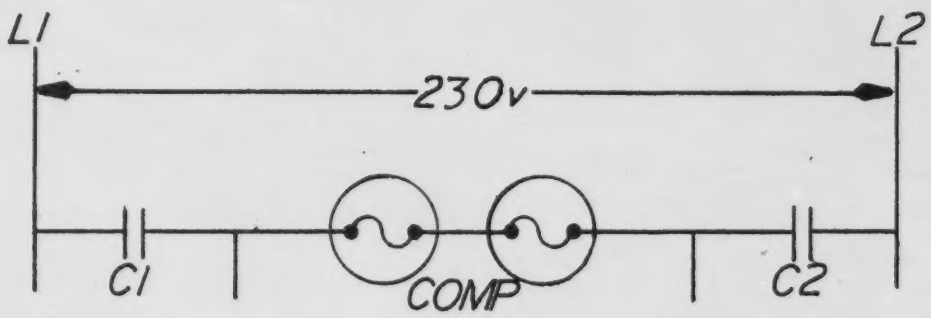
2. Select the components which will be needed to install the diagram on the plywood with the following exceptions:

   A. The compressor, CFM and IFM will be represented by two 110 volt light bulbs connected in series in order for them to burn.
   B. Do not wire a capacitor in the compressor circuit.
   C. Use SPST switches to represent the HP and LP switches.

3. Install the components on the plywood.

4. Make the proper wiring connections of the components for the system to operate properly.

   NOTE: The compressor circuit will look as follows:



5. Operate the system and let the instructor check the system.

Draw a wiring diagram to meet the following specifications.

SPECIFICATION A

1. Unit Type: Air cooled packaged unit
2. Power voltage: 230v - 11-60
3. Control voltage: 24v
4. DFM type: PSC motor (230-1-60)
5. IFM type: Shaded pole motor (230-1-60)
6. CFM will be cycled by thermostat connected in series with motor, thus controlling the head pressure.
7. The power feeding the CFM will be from the load side of the C.
8. Thermostat will be a three-wire cooling stat.
9. LP switch to cut compressor and CFM off.

1. From the diagram, mount the components on a piece of plywood.

2. Connect the proper wiring.

3. Any 230 volt loads will be represented by two 110v light bulbs connected in series. The CFM thermostat and the low pressure switch will be represented by SPST switches.

4. Operate control system.

Draw a wiring diagram to meet the following specifications.

SPECIFICATION B

1. Unit type: Air cooled package unit with remote condenser.
2. Power voltage: 208-1-60
3. Control voltage: 208 volts
4. Compressor type: 208-1-60
5. IFM type: 208v PSC motor with internal overload
6. IFM will operate constantly.
7. Control switch with OFF-FAN-COOL positions.
8. Magnetic starter for compressor control
9. LP switch
10. HP switch
11. Use auxiliary contacts of comp. magnetic starter to energize relay to start CFM.
12. Do not show CFM; just relay
13. Crankcase heater
14. Line voltage thermostat
15. IFM will operate at all times; it will not cycle with thermostat.

1. From the diagram mount the components on a piece of plywood.

2. Connect the proper wiring.

3. Any 230 volt loads will be represented by two 110 volt light bulbs connected in series. The LP and HP switch will be represented by SPST switches.

4. Operate control system.

MAJOR BLOCK Electricity **NAME** _____

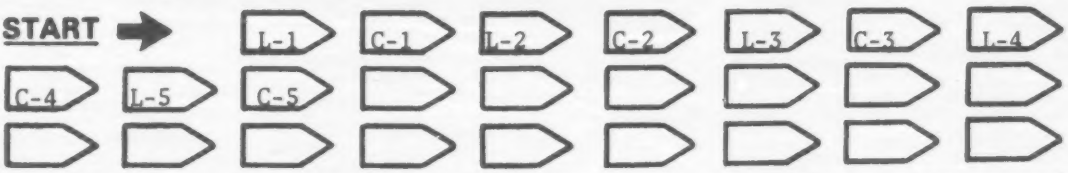
TASK Controls and Installation

UNIT Designing Advanced Control Panel **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-30

OBJECTIVE(S)

Design and Construct and Advanced Control Panel



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-30a
W-2
W-3
W-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-30a
L-2 Job Sheet EL-30b
L-3 Job Sheet EL-30c
L-4 Job Sheet EL-30d
L-5 Job Sheet EL-30e
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5
C-6
C-7
C-8
C-9

I. Obtain a 3' x 2' piece of plywood that will be needed to attach the components of the diagram studied in Text Assignment EL-30a

II. Select the components that will be needed to install the diagram on the plywood with the following exceptions:

1. The compressor, CFM, IFM, RVS, SHI, SH2, will be represented by two 110 volt light bulbs connected in series, in order for them to burn correctly.

2. Do not wire a capacitor in the compressor circuit; omit the capacitor circuit.

3. Use SPST switch to represent outdoor thermostats and air pressure switch in reversing valve solenoid circuit.

III. Install the components on the plywood.

IV. Use 230 volt as the power supply.

V. Make the proper wiring connections of the components for the system to operate.

VI. Operate the system and let the instructor check the control system.

I. Draw a wiring diagram to meet the following specifications:

SPECIFICATIONS C

1. Unit Type: Roof top-two stage cool and two stage heating.
2. Power voltage: 208-1-60
3. Control voltage: 24v
4. Compressor (2) type: PSC motors
5. Condensor fan motor (2) PSC motors
6. Indoor fan motor: PSC motor
7. Two stage heating - two stage cooling thermostat
8. Electric heaters (2) 208 volt
9. 1st compressor: 1st stage cooling
10. 2nd compressor: 2nd stage cooling
11. 1st heater: 1st stage heat
12. 2nd heater: 2nd stage heat
13. Thermostat in series #2 CFM to control head pressure
14. LP and HP switches
15. Current type pilot duty overloads for compressor

II. Let instructor check diagram.

I. Using the diagram made in the previous Job Sheet EL-30b, mount the components on a piece of plywood.

II. Connect the proper wiring for control system to operate properly.

III. Any 230 volt loads will be represented by two 110v light bulbs connected in series. The switches that are operated by pressure or high temperature will be represented by SPST switches.

IV. Operate control system.

I. Draw a wiring diagram to meet the following specifications:

SPECIFICATIONS D

1. Unit type: 10 ton condensing unit with two stage cooling.
2. Power voltage: 208-1-60
3. Control voltage: 24 volts
4. Control relay to operate compressor contactor
5. Contactor with 208 volt coil
6. First stage cool: Controls compressor
7. Second stage cool to control solenoid valve for #2 refrigerant circuit of evaporator.
8. Indoor fan motor controlled by thermostat
9. Magnetic starter controlling indoor fan motor.
10. Compressor: 208-1-60
11. CFM(2): 208-1-60 with internal overload
12. Second CFM controlled by HPS to maintain constant head pressure.
13. Compressor protected by current type pilot duty overload.
14. Crankcase heater controlled through control relay to energize heater on OFF cycle.
15. CFM motors controlled through control relay to operate when CR energized and CFM thermostat.
16. LP and HP switch for safety

II. Let instructor check the diagram.

I. Using the diagram developed in Job Sheet EL-30d, mount the components on a piece of plywood for specifications D.

II. Connect the proper wiring for control system to operate properly.

III. Any 230 volt load will be represented by two 110 v light bulbs connected in series. The switches operated by pressure or higher than normal temperatures will be represented by SPST switches.

IV. Operate control system.

MAJOR BLOCK Electricity **NAME** _____

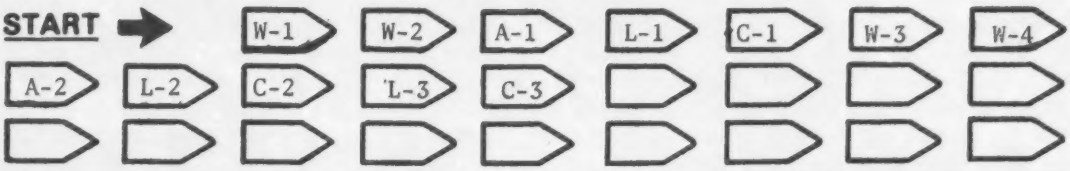
TASK Controls and Installation

UNIT Troubleshooting Electrical Control Systems (basic) **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-31

OBJECTIVE(S)

Identify problems in basic electrical control systems.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-31a
W-2 Text Assignment EL-31b
W-3 Assignment Sheet EL-31a
W-4 Information Sheet EL-31a
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-31a
A-2 Slide Set EL-31b
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-31a
L-2 Job Sheet EL-31b
L-3 Job Sheet EL-31c
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

I. Troubleshoot and List the Fault with the 20 Following Components Assigned by Instructor.

	FAULT
1. Thermostat #1	
2. Thermostat #2	
3. Transformer #1	
4. Compressor #1	
5. Compressor #2	
6. Compressor #3	
7. Overload #1	
8. Overload #2	
9. Overload #3	
10. Fuse	
11. Transformer #2	
12. Capacitor #1	
13. Capacitor #2	
14. Capacitor #3	
15. Relay #1	
16. Relay #2	
17. Relay #3	
18. Contactor #1	
19. Contactor #2	
20. Contactor #3	

Answer the following:

1. What is the best way to check the contacts of a contactor?

2. How does the service technician diagnose the condition of a set of contacts in a relay or contactor?

3. How does the service technician check fuses and circuit breakers?

4. How are line voltage overloads and pilot duty overloads different?

5. What is the procedure for checking a transformer?

6. What is the procedure for checking a pressure switch for proper operation?

7. What are the primary types of thermostats used in the refrigeration industry?

It is imperative for the service technician to approach a control troubleshooting situation in an orderly systematic manner. Take a minute or two to think about the problem at hand and to study the wiring diagram. Don't begin a troubleshooting job by randomly grabbing wires and testing them.

The following is a standard troubleshooting procedure which is applicable to most control circuits.

A. Check Power Supply

   1. If power is not available to unit, check fuses or circuit breakers.

B. Check Control Voltage

   1. If control voltage is not available check transformer or fuses.

C. Determine Loads on Operating

D. Find Loads on Wiring Diagram That are not Operating and Check Circuits

E. Hopscotch Circuit to Find Faulty Component (see Text Assignment EL-31b--p. 278 text #3)

F. Never Overlook Internal Overloads.

1. Troubleshoot the 5 Electrical Systems Assigned by the instructor

FAULTS

System #1

System #2

System #3

System #4

System #5

1. Troubleshoot the 5 Advanced Control Systems Assigned by the instructor

FAULTS

System #1

System #2

System #3

System #4

System #5

MAJOR BLOCK Electricity **NAME** _____

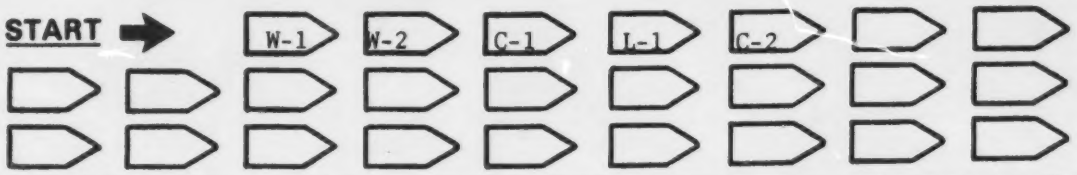
TASK Controls and Installation

UNIT Troubleshooting Electrical Control Systems (Advanced) **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-32

OBJECTIVE(S)

Identify problems in the electrical control systems.



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-32a
W-2 Assignment Sheet EL-32a
W-3 _____
W-4 _____
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-32a
L-2 _____
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Check point
C-2 _____
C-3 _____
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Assignment Sheet EL-32a

1. Write a basic procedure for troubleshooting control systems.

2. What three components are common to most all control systems?

3. What is the condenser fan motor controlled by? (on residential systems)

4. Safety controls which are used in small refrigeration systems are usually connected in _____ (parallel or series) with the contactor coil.

5. Why do large systems use a capacity control?

6. In troubleshooting language what is meant by "hopscotching"?

7. In diagnosing a basic refrigeration system what is the first thing a service-technician should look for?

8. System head pressure is maintained by the _____.

I. Troubleshoot 5 advanced control systems and complete data sheet.

Unit Number	Model # and Voltage	Type Unit	Fault
Unit #1			
Unit #2			
Unit #3			
Unit #4			
Unit #5			

MAJOR BLOCK Electricity **NAME** _____

TASK Controls and Installation

UNIT Servicing Solid-State Control Circuits **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-33

OBJECTIVE(S) You will be able to service solid-state control circuits using, as is required by the specific system being serviced, either a: whole-system tester; high resistance voltmeter; or continuity tester.

START → W-1 → A-1 → W-2 → C-1 → L-1 → C-2 → L-2 → C-3 → L-3 → C-4

WRITTEN ASSIGNMENT(S)

W-1	Information Sheet EL-33a
W-2	Assignment Sheet EL-33a
W-3	
W-4	
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide/Tape EL-33a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-33a
L-2	Job Sheet EL-33b
L-3	Job Sheet EL-33c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Solid-State Devices Used in Heating and Air Conditioning Control Circuits

The search for more efficient system operation has caused designers to turn to solar and environmentally produced heat as a source in answering system needs. Solar heat has many variables in its production and requires a large thermal storage area. Therefore, solar systems must be able to sense changes ongoing externally as well as internally and make timely changes in routing the heat transfer liquid between production, use and storage areas. Zone management looks at the heat producing environment within the structure and balances demands by shifting the heated air from one zone to another.

Systems built to take advantage of solar and environmentally produced heat rely upon continuous monitoring of conditions in all areas. To accomplish this, sensors are used and the information they produce is sent to a central analyzer which adjusts controls to maintain the system in balance. The need for quick processing of information from multiple sensors has promoted a shift from conventional control circuits to solid-state devices.

Solid-state devices have low current demands; therefore, many monitoring circuits may be used without appreciably increasing the operational (continuing) cost of the system. In addition to lower operational costs, the variety of control features available in solid-state devices allows for constructing system controls which may be programmed to meet specific structure changing use patterns. Such systems may include heat management principles such as: Zonal transfer, timed shut-down, partial shut-down, and changed operational reference. The latter is similar to the night-day dual thermostat used in conventional systems. However, for every feature added comes an increase in the number of factors a control system must consider to maintain a balanced condition. Solid-state devices are the logical step toward meeting these compounded needs.

Terms Used to Describe Solid-State Control

Mini-Computer: A circuit which receives multiple input signals and contains an internal reference with which to compare these inputs and develop controlling the output current for maintaining system balance.

Logic Board: A non conductive mounting surface which has an an integral part the electronic circuit which serves as as a mini-computer.

Printed Circuit(PC) Board: A non-conductive mounting surface which has a network of conductors applied to its surface by using techniques similar to those of the printing process. The term is often applied to a complete, self-contained solid-state circuit.

Integrated Circuit(IC): A group of diodes, transistors, resistors, capacitors and other solid state devices incorporated into a complete unit. The term may be applied to a single component mounted on a printed circuit board or be used as a general reference to the complete circuit.

Chip: A trade developed term which refers to an IC module constructed for a specialized purpose.

Chipboard: The PC upon which the ICs are mounted.

Module: A PC constructed to process sensor information and develop system control current.

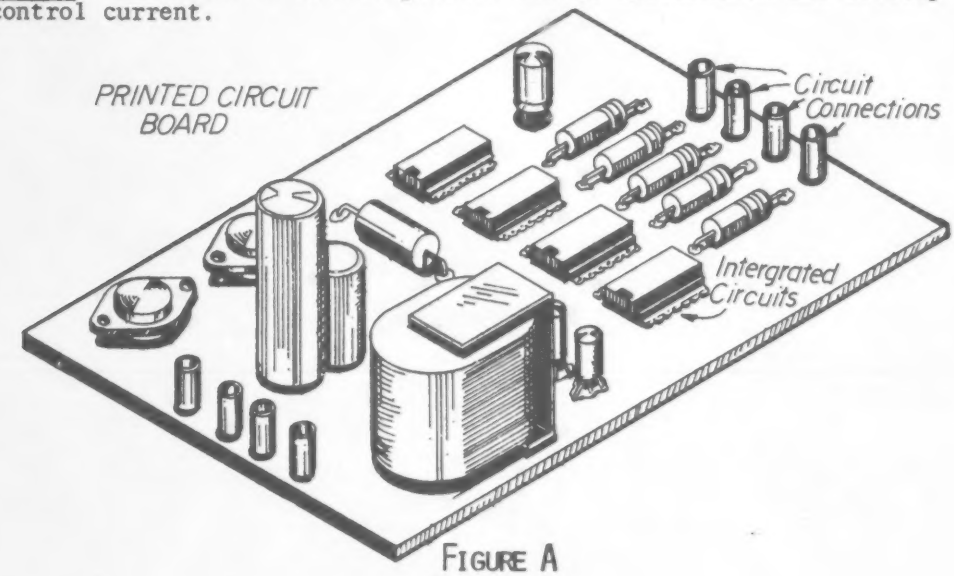


FIGURE A

A Solid-State Control Circuit

A module often appears in wiring diagrams as a box with terminal points for the input signals from sensors and other terminal points for output current for the controlled units such as the relays which control circulating pumps, fan motors, mixing unit control motors. The diagram below illustrates the symbol representing a module which is used as the defrost control. While each individual component of the PC is not illustrated in the diagram, a service technician, by analyzing the function of the attaching components, can determine the purpose of the module.

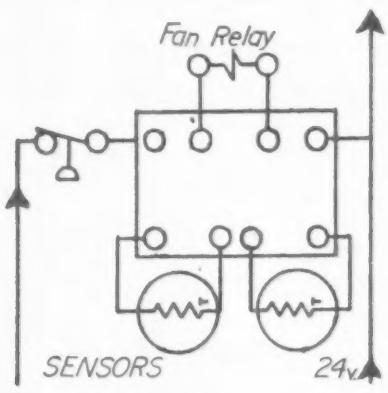


FIGURE B

Symptoms of Solid State Control Circuit Failure

The range of symptoms associated with these controls is similar to those encountered in servicing conventional control circuits. Many of the troubleshooting charts developed by manufacturers for use in isolating the faulty components are helpful in analyzing solid-state control systems. Fortunately solid-state devices are very reliable because they have been constructed to operate in extreme environmental conditions. Except for the "burning" conditions caused by shorts of nearby attaching units or lightning, a solid-state control circuit is usually trouble free and is not usually the source of a problem.

If after careful analysis of the symptoms the solid state module is suspected as being faulty, perform circuit test before making a decision to replace the circuit.

Testing Solid State Control Circuits

Manufacturers Alignment and Fault Detector Tester: Many manufacturers have turned to whole system analyzers to aid their service technicians in alignment and fault detection tasks. If this tester is available, then use it according to the procedures given in the service data.

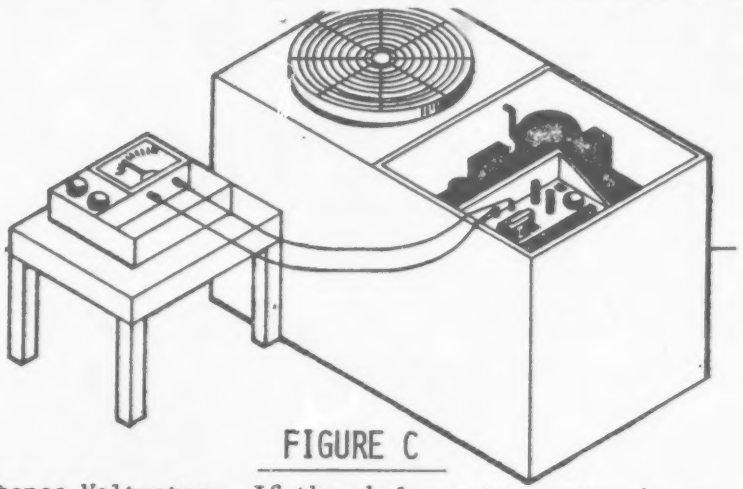


FIGURE C

High Resistance Voltmeter: If the whole-system tester is not available then a high resistance voltmeter, one with a high ohms-per-volt ratio, should be used. You must be familiar with the normal voltage levels present at input and output terminals and you also must know the normal resistance levels of circuit components. This information may be in the service data or you may have to develop the data by reading the data plates attached to components.

The information obtained from a parts catalog may also be of use in understanding normal circuit conditions.

CAUTION: When checking terminals on PC board be careful not to short across contacts. Careless handling of test probes burn out a board component and may result in board replacement which otherwise would not be needed.

Remember, it is advisable to thoroughly test all associated system components before considering the PC board as the faulty component.

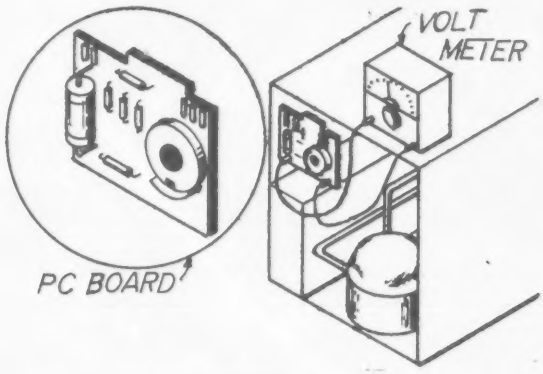


FIGURE D

Continuity Tester: Although the most limited of the three types of testers is a continuity tester, a servicing technician can usually perform sufficient tests to isolate the faulty component. This tester is designed for use on low resistance circuits and is <u>not</u> suitable for trouble-shooting PC board components. Once contacts, switches, relay coils and lines have been checked and determined to be serviceable and the location of the fault has been narrowed to one or several components the technician who is limited to only a continuity tester must turn to component substitution as a route to clearing the malfunction.

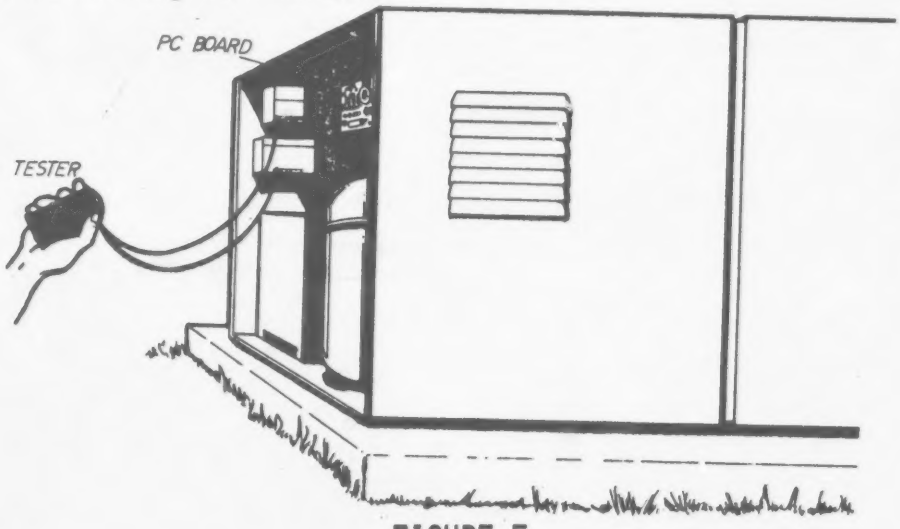


FIGURE E

Identifying Solid-State Devices and Solid-State Servicing Procedures.

Supply your response as necessary and when you have completed this assignment, have it checked by your instructor.

1. Efficient use of solar and environmentally produced heat requires timely transfer of the heat medium between _____, _____ and _____ areas.

2. Monitoring conditions in all areas is accomplished by a _____ in each _____.

3. An advantage of solid-state devices which results in low operational cost of control circuits is the _____ required.

4. The symbol used to indicate a module is usually a _____ with terminal points for input signals from _____ and other terminals supplying current to _____.

5. Place the number of the statement, below left, which agrees with the term, below right, on the line following the term. CAUTION: Not all statements apply to terms given.

Statements	Terms
1. A group of diodes, transistors, resistors, capacitors and other solid-state devices incorporated into a complete unit.	Mini-Computer _____
2. A non-conductive mounting surface which has a network of conductors applied to its surface using techniques similar to print processes.	Logic Board _____
3. A trade developed term for an IC module constructed for a specific purpose.	
4. A circuit which receives multible inputs, develops output current, and has an internal reference.	Printed Circuit Board _____
5. The PC upon which the IC's are mounted.	Integrated Circuit _____

6. A non-conductive mounting surface which has as an integral part the electronic circuit which serves as a mini-computer. Chip _____

7. A unit with three current carriers separated by barrier regions Chip Board _____

8. A PC constructed to process sensor information and develop system control currents. Module _____

6. Circle Correct Word: The range of symptoms associated with solid state control circuits is (different/similar) when compared to conventional control circuits.

7. When symptom analysis indicates a control module is defective, your next step is to _____.

8. The preferred item of equipment for troubleshooting a system with solid-state controls is a _____.

9. A "general service" equipment item which causes minimum loading of the circuit being tested is the _____.

10. Describe the precautions you would take when checking terminal on a PC Board. _____
_____
_____
_____.

Servicing Solid-State Control Devices with a Whole System Tester

PART I: Contact your instructor for information concerning the system which is used for this project. When you have this information, fill in the blanks.

System Data:

Manufacturer: _____ Model _____
Serial Number: _____
Symptoms: _____

_____

_____

Service References Used: _____

_____

_____

Test Equipment:

Noun: _____ Model: _____
Serial Number: _____

Additional Items:

Noun: _____ Model: _____
Serial Number: _____

Test Performed: _____

_____

_____

Test Results: _____

_____

_____

Repair or Replace Decision: _____

_____

NOTE: Before proceeding to Part II, have your responses for Part I reviewed by your instructor.

PART II: Corrective Action Taken: _____

_____

Servicing Solid-State Control Devices with a High Resistance Voltmeter

PART I: Contact your instructor for information concerning the system which is used for this project. When you have this information, fill in the blanks.

System Data:

Manufacturer: _____ Model: _____
Serial Number: _____

Symptoms: _____

_____

_____

Service References Used: _____

_____

_____

Test Equipment:

Noun: _____ Model: _____
Serial Number: _____

Additional Items:

Noun: _____ Model: _____
Serial Number: _____

Test Performed: _____

_____

_____

Test Results: _____

_____

_____

Repair or Replace Decision: _____

_____

NOTE: Before proceeding to Part II, have your responses for Part I reviewed by your instructor.

PART II: Corrective Action Taken: _____

_____

Servicing Solid-State Control Devices with a Continuity Tester

PART I: Contact your instructor for information concerning the system which is used for this project. When you have this information, fill in the blanks.

System Data:

Manufacturer: _____ Model: _____
Serial Number: _____

Symptoms: _____

_____

_____

Service References Used: _____

_____

_____

Test Equipment:

Noun: _____ Model: _____
Serial Number: _____

Additional Items:

Noun: _____ Model: _____
Serial Number: _____

Test Performed: _____

_____

_____

Test Results: _____

_____

_____

Repair or Replace Decision: _____

_____

NOTE: Before proceeding to Part II, have your responses for Part I reviewed by your instructor.

PART II: Corrective Action Taken: _____

_____